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An Assessment of Potential Critical Habitat for Nooksack Dace (*Rhinichthys cataractae* ssp.) and Salish Sucker (*Catostomus sp.*)

Évaluation de l'habitat essentiel potentiel du naseux de Nooksack (*Rhinichthys cataractae*) et du meunier de Salis (*espèce Catostomus*)

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Abstract

Potential critical habitat (PCH) is defined for Salish sucker and Nooksack dace. PCH is identified and mapped using reach-scale, in-stream habitat characteristics. PCH includes 166 km of channel and 328 km of bank in140 reaches and 11 watersheds. The width of riparian reserve necessary to maintain important habitat characteristics is included in PCH and was assessed using an adaptation of British Columbia's Riparian Area Regulation (RAR) assessment methodology. It extends laterally from the top of bank along both banks of the full length of each potential critical habitat reach to a distance equal to the widest zone of sensitivity (ZOS) calculated for each of 5 riparian features, functions and conditions. These are: large woody debris supply for fish habitat and maintenance of channel morphology, localized bank stability, channel movement, shade, and insect and debris fall. Widths of riparian reserve in PCH reaches range from 5 to 30 m, with an average of 21.4 m (s. dev = 6.77) and total area encompasses 717 ha of land.

Existing riparian vegetation in PCH is sparse, with 60% of bank length supporting discontinuous bands of vegetation less than 5 m wide. This highlights the need for recovery activities focused on riparian enhancement and restoration. Permanent structures such as roads, farm crossings, buildings, and yards restrict the width of 106 km (32%) of riparian reserve within PCH to less than its calculated value. Actively farmed land and golf course fairways impinge on an additional 112 km (34%) of PCH length. Protecting this land is a priority for conserving these species and would provide benefits to a number of other *SARA* listed species, in addition to salmonids, surface water quality, and (in many cases) agricultural drainage.

Résumé

L'habitat essentiel potentiel du naseux de Nooksack et du meunier de Salish a été défini. Cet habitat est délimité et cartographié à l'aide de caractéristiques de l'habitat à l'échelle d'un tronçon de cours d'eau. Il comprend 166 km de chenal et 328 km de rives dans 140 tronçons et 11 bassins hydrographiques. La largeur de la réserve riveraine nécessaire au maintien des caractéristiques importantes de l'habitat est comprise dans l'habitat essentiel potentiel et a été évaluée au moyen d'une adaptation d'une méthode d'évaluation prévue par le règlement de la Colombie-Britannique sur les zones riveraines. Elle s'étend latéralement à partir de la laisse de haute mer, le long des deux rives sur toute la longueur de chaque tronçon d'habitat essentiel potentiel, jusqu'à un point à une distance égale à la plus large zone de sensibilité calculée pour chacune des 5 caractéristiques, fonctions et conditions riveraines, soit : une grande réserve de débris ligneux pour l'habitat du poisson et le maintien de la morphologie du chenal, la stabilité locale des rives, le mouvement du chenal, l'ombrage, les insectes et la chute de débris. La largeur des réserves riveraines dans les zones d'habitat essentiel potentiel varie entre 5 et 30 m, avec une moyenne de 21,4 m (écart-type = 6,77) et la zone totale englobe 717 ha de terrain.

La végétation riveraine existante dans les zones d'habitat riverain essentiel est éparse, puisque l'on trouve sur 60 % de la longueur des rives des bandes discontinues de végétation de moins de 5 m, ce qui fait ressortir la nécessité d'entreprendre des activités de rétablissement axées sur la mise en valeur et la remise en état des rives. Les structures permanentes telles que les routes, les passages à niveau de ferme, les bâtiments et les cours, réduisent la largeur de 106 km (32 %) de réserves riveraines dans l'habitat essentiel potentiel à moins que la valeur calculée. Les terrains cultivés et les parcours de golf empiètent sur une autre portion de 112 km (34 %) de la longueur de l'habitat essentiel potentiel. La protection de ces terres est donc une priorité si l'on veut conserver ces espèces. De plus, elle aurait des retombées positives sur un certain nombre d'autres espèces figurant dans la liste de la LEP, outre les salmonidés, sur la qualité de l'eau de surface et, dans bien des cas, sur le drainage agricole.

Disclaimer

This Draft Assessment of critical habitat for Nooksack dace and Salish sucker has been prepared in cooperation with the members of the Non-Game Freshwater Fishes Recovery Team (BC). It defines the biological basis of critical habitat definition. It does not necessarily represent the views of all individual members of the recovery team, or the official positions of the organizations with which the individual team members are associated. The critical habitat definitions and rationale are based on the best available knowledge and are subject to modifications resulting from new findings and revised objectives.

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Introduction

The federal *Species at Risk Act* (*SARA*) requires that habitat '*necessary for the survival or recovery of listed species'* be identified to the extent possible, and proposed for designation (and protection) as critical habitat. For aquatic species *SARA* prohibits the destruction of any part of designated critical habitat wherever it occurs (s. 58).

In this report, I assess and map potential critical habitat for Salish sucker and Nooksack dace using definitions and guidelines consistent with the Recovery Strategies (Pearson et al. 2007a, b). Potential critical habitat (PCH) includes all habitats within occupied watersheds that the Recovery Team considers of high quality or potentially high quality for Salish sucker or Nooksack dace, and constitutes the habitat that the Recovery Team deems necessary for species persistence, and to achieve recovery objectives. It includes habitats that are presently degraded and unoccupied, but are believed to have been occupied historically.

PCH was defined using in-stream habitat characteristics at the scale of the reach, a natural unit of stream habitat that ranges from hundreds to thousands of metres in length (Frissell et al. 1986). There are three reasons for adopting this scale. First, the reach scale corresponds to the distribution of subpopulations of both species within watersheds and usually contains all habitat types used during the life history cycle (Pearson, 2004). Second, the 'channel units' of potential critical habitat (riffles and pools) are dynamic and frequently move during flood events in these streams. Effective protection and management of critical habitat in these circumstances must allow for normal channel processes and must, therefore, occur at a spatial scale larger than the channel unit. The reach scale is the next largest in accepted stream habitat classifications (Frissell et al. 1986; Imhof et al. 1996) and by definition represents relatively homogenous segments of stream demarcated by distinct geomorphic or landuse transitions. Third, the reach scale corresponds most closely to that of land ownership in these watersheds and, consequently, to most potential recovery actions. In total, the report identifies 140 reaches in 11 watersheds, totaling approximately 166 km of channel as potential critical habitat.

PCH includes riparian reserve areas. Reserve widths are assessed using a GIS based methodology adapted directly from and consistent with that of the British Columbia Riparian Area Regulation (RAR, Reg. 837 under the Fish Protection Act (S.B.C. 1997, c. 21) Anonymous 2005). The width of existing riparian vegetation and areas where riparian reserve width is restricted by permanent structures (roads, buildings, yards etc.) are also mapped.

Nooksack Dace

Potential Critical Habitat

Definition

Potential critical Habitat (PCH) for Nooksack dace consists of reaches in their native creeks that consist of (or are known to have previously consisted of) more than 10% riffle by length. It includes all aquatic habitats and riparian reserve strips of native vegetation on both banks for the entire length of the reach. Reserve strips are continuous and extend laterally from the top of bank to a width equal to the widest zone of sensitivity (ZOS) calculated for each of five riparian features, functions and conditions: large woody debris supply for fish habitat and maintenance of channel morphology, localized bank stability, channel movement, shade, and insect and debris fall. The ZOS values are calculated using methods consistent with those used under the British Columbia Riparian Areas Regulation (Reg. 837) under the Fish Protection Act (S.B.C. 1997, c. 21).

The combined length of potential critical habitat for Nooksack dace is 33.1 km (of 93.9 km of surveyed stream channel). Figure 1 shows the linear extent of potential critical habitat for Nooksack dace in Bertrand Creek. Similar maps showing the extent of potential critical habitat for the other watersheds known to contain Nooksack dace are provided in Appendix 1, under separate cover.

Riparian habitat that falls outside of the definition above (e.g. upstream reaches) may also be recommended as PCH in the future if it is demonstrated to be a large and chronic source of sediment that is negatively impacting downstream critical habitat.

Rationale

Riffle Habitat

Available information overwhelmingly indicates that Nooksack dace require riffle habitats and that reaches with a high percentage of riffle habitats support most of the population. Nooksack dace typically occur in riffles with loose gravel and cobble substrates where water velocity exceeds 0.25 $m \cdot s^{-1}$. They spawn near the upstream end of riffles (McPhail 1997) between late April and early July (Pearson 2004) and forage nocturnally for riffle dwelling insects (McPhail 1997). Logistic regression relating Nooksack dace presence to habitat type (riffle, shallow pool etc.), cover availability and riparian land use showed that reach occupancy was most strongly predicted by the amount of riffle habitat present, and that riffles isolated by long stretches of deep pool are seldom inhabited (Pearson, 2004). The proposed threshold of 10% riffle by length is intended to exclude reaches with very small amounts of riffle habitat that contribute minimally to Nooksack dace production and population size.

A number of reaches containing less than 10% riffle by length when surveyed are included in potential critical habitat (Table 1) because of evidence that they previously contained more riffle habitat and supported Nooksack dace populations. Most of these reaches are known to have been channelized and dredged or were temporarily impounded by beaver at the time of survey. All currently contain Nooksack dace except four reaches in Fishtrap Creek. These are known to have contained abundant riffle and Nooksack dace prior to dredging (J.D. McPhail pers. comm.). The remaining (non PCH) reaches in all watersheds contain a total of 490 m^2 of riffle habitat, or 1.9% of the total riffle habitat present.

Shallow Pool Habitat

Young-of-the-year Nooksack dace inhabit shallow (10-20 cm) pools adjacent to riffles where they swim above sand, mud, or leaf litter substrates and feed upon chironomid pupae and ostracods (McPhail 1997). Insofar as these habitats are exclusively used for larval rearing before juveniles move in to riffle habitat, the loss of these habitats would likely cause population declines.

Riparian Habitat

Riparian vegetation is included in potential critical habitat to the extent necessary to protect the integrity of in-stream potential critical habitat. Loss of riparian vegetation will result in bank erosion, siltation, water temperature elevation, and nutrient inputs that will directly degrade instream critical habitat. Required widths will vary among sites and are defined in reach scale assessments (see below). Reserves must be sufficient to control sediment entry to the stream from overland flow, to prevent excessive bank erosion and to buffer stream temperatures. Reserve areas will also remove significant amounts of nitrate and phosphorous from groundwater, although their efficiency depends strongly on hydrogeologic conditions (Martin et al. 1999; Puckett 2004; Wigington et al. 2003). The effectiveness of a riparian reserve in preventing materials (sediment, nutrients, toxins, etc.) from entering a stream depends upon on its continuity in addition to its width, particularly when it is narrow (Weller et al. 1998). Consequently, riparian reserves in critical habitat reaches should be continuous. In open landscapes, such as agricultural fields, vegetation from reserve areas will collect windblown insects (Whitaker et al. 2000). Such insects, falling from riparian vegetation into the water constitute an important food source in headwater streams (Allan et al. 2003; Schlosser 1991). More than 30 m of riparian vegetation may be required for full mitigation of warming (Brown & Krygier 1970; Castelle et al. 1994; Lynch et al. 1984), and siltation (Davies & Nelson 1994; Kiffney et al. 2003; Moring 1982), and for long-term maintenance of channel morphology (Murphy et al. 1986; Murphy & Koski 1989). At least 10 m are required to maintain levels of terrestrial food inputs similar to those of forested landscapes (Culp & Davies 1983). Reserves as narrow as 5 m provide significant protection from bank erosion and sediment deposition from overland flow (Lee et al. 2003; McKergow et al. 2003).

Failure to maintain an adequate riparian reserve as part of critical habitat is likely to cause population-level impacts. In habitats lacking sufficient flow or groundwater, absence of shade may increase water temperatures to harmful levels, especially under climate warming scenarios. Increased erosion due to poor bank stability will cause direct sediment deposition in riffles, impairing spawning and incubation, reducing food availability, and eliminating the spaces in coarse substrate that Nooksack dace and their prey occupy. Nutrient loading will be higher in reaches without adequate riparian vegetation (Dhondt et al. 2002; Lee et al. 2003; Martin et al. 1999) and is likely to contribute to hypoxia through eutrophication. Increased solar radiation in nutrient rich reaches lacking adequate riparian shading (Kiffney et al. 2003) will also contribute to eutrophication and hypoxia.

Width of riparian reserves required to protect key habitat attributes for Nooksack dace have not been quantified. *R. cataractae* is certainly less dependant upon deep pool habitats than salmonids are, suggesting somewhat lesser requirements for large woody debris. They also favour benthic over drifting invertebrates (Scott & Crossman 1973) suggesting they are less dependant on insects of terrestrial origin. *R. cataractae* appear tolerant of slightly higher water temperatures than salmonids (Wehrly et al. 2003), suggesting a reduced need for shading, but this may not be true under future climate warming scenarios. However, Nooksack dace are likely to be equally or more vulnerable than salmonids to habitat degradation caused by sedimentation, loss of scope for natural channel movement, and invasive plant overgrowth of riffles fuelled by nutrient loading and riparian loss. Benthic insectivores and fluvial specialists, like Nooksack dace, are among the most sensitive fish species to loss of wooded riparian areas (Stauffer et al. 2000), probably due to the impacts of siltation and alterations to macroinvertebrate community structure (Allan 2004; Kiffney et al. 2003). Overall, there is little reason to believe that Nooksack dace require narrower buffers than salmonids.

BC MOE and DFO have developed and implemented a methodology for determining riparian reserve widths required to protect fish habitat in streams that they deem to be minimally sufficient in maintaining riparian function to protect fish habitat. The Riparian Area Regulation (RAR) was developed under the *Fish Protection Act* to protect "salmonids, game fish, and regionally significant fish" from the impacts of land development. In the absence of definitive data for a *SARA* listed species, this seem to be a reasonable standard to apply in the identification of PCH, as it is represents a benchmark and standard methodology to which both federal and provincial agencies responsible for management of species at risk have already agreed, and it forms the basis of the methodology employed (see below). The width of riparian buffers sufficient to protect fish habitat is a scientific discipline in itself, and it is neither practical nor within the mandate of the Recovery Team to develop an independent assessment methodology and regulatory framework.

Finally, it should be noted that unidirectional transport of sediment in flowing waters means that riparian reserve strips upstream of PCH reaches are important in minimizing sedimentation and other impacts within PCH. For this reason stewardship programs should promote the establishment of continuous riparian reserve strips of native vegetation throughout the watershed, not just along PCH reaches. While local sediment inputs within occupied reaches are likely the most important sources of sediment that require protection, the future designation of critical habitat to protect riparian zones on specific upstream reaches should remain a management option, particularly if specific locations can be identified as significant sources of sediment that degrade critical downstream habitat.

Table 1: Reaches included in potential critical habitat for Nooksack dace that contained less than 10% riffle by length at the time of survey (1999).

Watershed	Reach	Length	Riffle Length	Riffle Area	% Riffle by Length	Dace Present	Condition
Bertrand	BTD5	652	40	112	6.1	Y	Channelized and dredged
	BTD7	449	29	58	6.5	Y	Partially impounded by beaver
	BTD8	1139	44	176	3.9	Y	Partially impounded by beaver
	BTD9	1104	57	200	5.2	Y	Channelized
	BTD18	637	35	88	5.5	Y	Channelized
Fishtrap	FTP1	1984	170	459	8.6	N	Dredged 1990-1991
	FTP2	1239	72	144	5.8	Y	Dredged 1990-1991
	FTP3	962	15	33	1.6	N	Dredged 1990-1991
	FTP6	926	66	198	7.1	N	Dredged 1990-1991
	FTP12	476	32	19	6.7	N	Channelized
Pepin	PEP1	263	5	13	1.9	Y	Channelized and dredged

Amount of Critical Habitat Required

The amount of critical habitat required to meet a recovery target needs to be based on population targets derived from credible area-abundance relationships or, ideally, robust population viability analyses (Rosenfeld & Hatfield 2006). Unfortunately the necessary demographic data for population viability analysis are lacking for Nooksack dace and area-abundance relationships remain highly uncertain, primarily due to difficulties in sampling. Habitats with large cobble and boulder substrates often support the highest density of Nooksack dace, yet cannot be effectively sampled with kick seines due to substrate immobility or by electrofishing, as stunned fish frequently become stuck in crevasses and cannot be retrieved, if they are even seen. An attempt to estimate density using mark-recapture data from an intensive minnow trapping study failed due to low recapture rates (Pearson, 2004).

In these circumstances, an appropriate guideline for minimum viable population (MVP) must be estimated from values for other species. Based on an extensive review of the scientific literature (Reed et al. 2003; Thomas 1990), mean MVP for vertebrate species is approximately 7300 breeding adults (median = 5800; n =102; range 2000-10000). From these data, an abundance of reproductive adults in the low to mid thousands is considered adequate to maintain genetic diversity and to buffer the population from random variations in survival, and thus to maintain long-term viability in the absence of deterministic factors causing the population to decline.

Populations of Nooksack dace in each of the four watersheds are essentially independent of one another, with low probability of natural exchange of individuals between watersheds because of the large distances of unsuitable habitat that separate populations (McPhail, 1997, Pearson, 2004). Natural recolonization of a watershed from which a population has been extirpated (rescue effect) is highly unlikely. Each watershed, consequently, warrants a separate recovery target in the low to mid thousands.

Sufficient density and habitat availability information does exist to estimate an upper bound for current Nooksack dace populations in the various streams (Table 2). High quality habitat in Bertrand Creek supported an average of 1.9 dace/m^{-2} (n=20, SE = 0.35) (Inglis et al. 1994). If all riffle areas in all potential critical habitat reaches supported this density, total adult abundance would be in the low thousands in the Bertrand, Pepin and Fishtrap Creek watersheds (Table 2). This suggests that the maximum achievable population size is close to the average minimum viable population size for vertebrate populations and that all potential critical habitats identified by the criteria above require designation. Due to an abundance of riffle area, the Brunette River would support over 38,000 adult Nooksack dace if all habitat meeting the definition potential riparian critical habitat was occupied at this density. Sampling data from September 2007 (Pearson unpubl.), however, found that only one reach (BRN2) constituting 34% of channel length identified as PCH is currently occupied by Nooksack dace, and that densities are far lower than 1.9 dace/m^{2} where they do occur (maximum density estimated from electroshocking or kick seining data was 0.5 dace/m^{2}; n =

132 hauls in 7 reaches). As the reach contains only 7650 m^2 of riffle, this density throughout would equate to a population of only 3,825 dace. Relative CPUE for minnow trapping in Pepin Brook and Fishtrap Creek also suggest that actual densities are very low relative to those of Bertrand Creek (COSEWIC 2007).

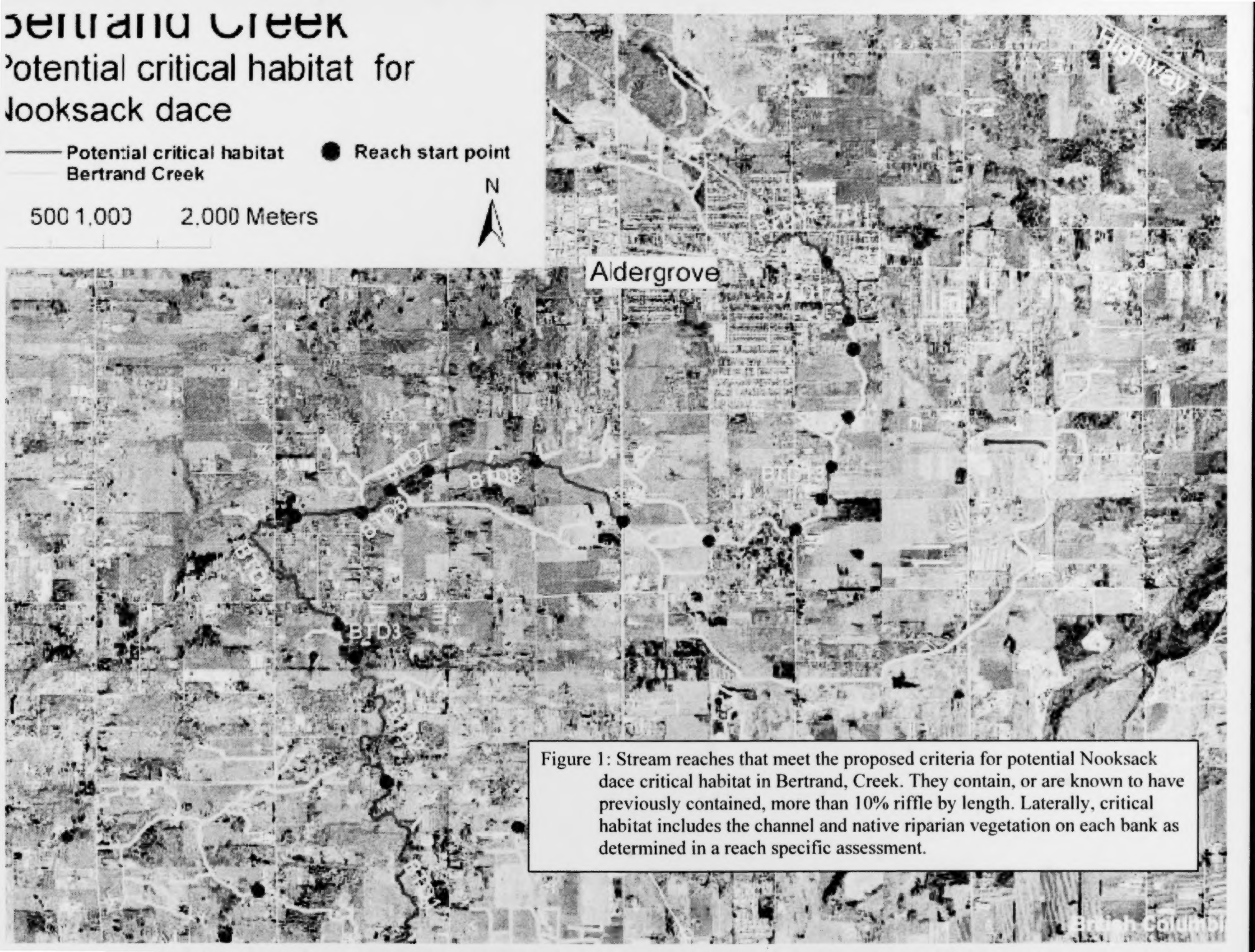
ertrand Creek
otential critical habitat for
ooksack dace
Potential critical habitat
Bertrand Creek
Reach start point
N
500 1,000 2,000 Meters
Highway 1
Aldergrove
BTD7
BTD8
BTD3

Figure 1: Stream reaches that meet the proposed criteria for potential Nooksack dace critical habitat in Bertrand, Creek. They contain, or are known to have previously contained, more than 10% riffle by length. Laterally, critical habitat includes the channel and native riparian vegetation on each bank as determined in a reach specific assessment.

Table 2: Estimates of channel length and riffle area of potential critical habitat reaches for Nooksack dace, their estimated carrying capacity, and the length currently occupied.

Watershed	Total Potential Critical Habitat (km)	Area of Riffle in Potential Critical Habitat (m^2)	Estimated 'Carrying Capacity' of Potential Critical Habitat* (Number of adults)	Length of Potential Critical Habitat Occupied (km)
Bertrand Creek	10.0	3000	5700	<6.5 (2004)
Pepin Brook	2.8	2300	4400	<2 (2004)
Fishtrap Creek	8.5	2030	3900	unknown
Brunette River	11.4	20150	38285	<3.9 km

*Assumes an average density of 1.9 Nooksack dace per m^2 riffle (Inglis et al. 1994). These estimates should be considered maxima as not all potential critical habitat is of high quality. Only 7650 m^2 of PCH in the Brunette River is currently occupied. Area and carrying capacity estimates are rounded to nearest hundred.

In addition to the population-based criteria above, the quantity of critical habitat required can also be based on the listing criteria, and the recovery goals and objectives for the species. Nooksack Dace were listed because of a limited number of populations and loss of habitat. All existing occupied habitat is therefore required to move the species towards delisting (which may never occur because the limited distribution will always keep the species at risk). Recovery goals in the Recovery Strategy also explicitly require self-sustaining populations throughout their native distribution, which requires populations that are likely to persist without dependence on rescue from another population. Multiple populations are required to increase the probability of a rescue effects (i.e. should a population be extirpated due to, for instance, a chemical spill in a stream that does no long-term habitat damage), but the rescue effect cannot be effective if habitat in a population is allowed to degrade and a population declines in size so that it is demographically vulnerable to stochastic extinction.

Activities Likely to Destroy Critical Habitat for Nooksack Dace

SARA requires that activities likely to result in the destruction of critical habitat be listed and described. Table 3 provides this information for Nooksack dace.

Table 3: Activities likely to result in the destruction of potential critical habitat for Nooksack dace.

Activity	Description
Excessive water withdrawal	Water extraction (surface or ground) during dry periods reduces flows, which may contribute to hypoxia and drying of riffles and the primary habitat.
Excessive sediment releases	Sediment deposition in substrate and inhibition of the flow of oxygen-rich water to eggs and larvae during incubation.
Drainage projects	Dredging, dyking, and channelization works directly destroy habitat, cause sediment deposition in riffles, and reduce base flow,
Impoundment	Ponding caused by either human or beaver activities eliminated riffle habitat.
Urban storm drainage	Storm drain systems that discharge directly to creeks are major sources of toxic contamination and sediment. They also reduce baseflow by inhibiting water infiltration to aquifers.
Riparian vegetation removal	Loss of vegetation exposes a stream to increased erosion and sediment deposition, elevated water temperatures, reduced supplies of terrestrially derived food, and increased nutrient loading
Livestock access to creeks	Livestock damage habitat by trampling or causing erosion that clogs riffles with sediment. Access also contributes to nutrient loading.

Activity	**Bertrand Creek**	**Pepin Brook**	**Fishtrap Creek**	**Brunette River**
Excessive water withdrawal	+++	+	++	+
Excessive sediment releases	+	+++	++	++
Drainage projects	++	+	+++	-
Impoundment	+	+++	++	+
Urban storm drainage	+++	-	+++	+++
Riparian vegetation removal	++	+	+++	+
Livestock access to creeks	+	+	+	-

+++	major concern	+	minor concern
++	moderate concern	-	not a concern

Salish Sucker

Potential Critical Habitat

Definition

Potential critical habitat (PCH) for Salish sucker includes all reaches in streams currently containing populations than contain more than 50 m of continuous pool that exceeds 70 cm depth at low flow. It includes all aquatic habitat and riparian reserve strips of native vegetation on both banks for the entire length of the reach. Reserve strips are continuous and extend laterally from the top of bank to a width equal to the widest zone of sensitivity (ZOS) calculated for each of five riparian features, functions and conditions: large woody debris supply for fish habitat and maintenance of channel morphology, localized bank stability, channel movement, shade, and insect and debris fall. The ZOS values are calculated using methods consistent with those used under the British Columbia Riparian Areas Regulation (Reg. 837) under the Fish Protection Act (S.B.C. 1997, c. 21).

Habitat that falls outside the definition above may also be identified as PCH if it is known to be important for spawning, rearing, migration, or temporary refuge (e.g. from lack of water in headwater reaches). Mapping of potential critical habitat is complete or near completion for the 10 known populations. It includes 141.5 of 289.5 km of surveyed channel and is provided in Appendix 1.

Rationale

Deep Pool Habitat

Salish sucker adults and larger juveniles (>70 mm) are concentrated in reaches containing long stretches of pool habitat that exceed 70 cm in depth at low flow. These habitats contribute disproportionately to population size (Pearson 2004). As the primary habitat for the majority of the life cycle, all deep pool habitats in reaches containing more than 50 m of continuous channel where depth exceeds 70 cm are included in PCH. The 50 m threshold was chosen because it is the minimum length that includes all reaches known to contain moderate or high densities of Salish sucker (catch per unit effort > 1.8 individual per trap[1], Pearson 2004.). It also includes reaches containing excellent physical habitat, where severe hypoxia appears to exclude or limit the abundance of Salish suckers.

Riffle Habitat

Riffles, which are used for spawning by Salish suckers, tend to be rare (and potentially limiting) in the reaches occupied by high densities of Salish suckers, which consist predominantly of headwater ponds and marshes (Pearson 2004). Consequently, all riffle habitats within reaches containing more than 50 m of habitat with water depths exceeding 70 cm is potentially critical. In some reaches, fish leave their 'home' reach to spawn (Pearson & Healey 2003). These spawning areas are also potential critical habitat.

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[1] Double ended cylindrical funnel traps 100 x 55 cm, 0.5" mesh, baited with dry cat food set for 24 h (see Pearson and Healey 2003).

Shallow Pool and Glide Habitats
Shallow pools and glides are used by young-of-the-year Salish suckers (<70 mm fork length; <40 cm depth), although they are occasionally captured in deeper water (Pearson 2004). All shallow pool and glide habitats within reaches containing more than 50 m of continuous habitat with water depths exceeding 70 cm is considered PCH, as it is may be limiting as nursery habitat.

Riparian Habitat
Riparian vegetation is included in potential critical habitat to the extent necessary to protect the integrity of in-stream potential critical habitat. Loss of riparian vegetation will result in bank erosion, siltation, water temperature elevation, and nutrient inputs that will directly degrade instream critical habitat. Required widths will vary among sites and are defined in reach scale assessments (see below).

Reserves must be sufficient to control sediment entry to the stream from overland flow, to prevent excessive bank erosion and to buffer stream temperatures. Reserve areas will also remove significant amounts of nitrate and phosphorous from groundwater, although their efficiency depends strongly on hydrogeologic conditions (Martin et al. 1999; Puckett 2004; Wigington et al. 2003). The effectiveness of a riparian reserve in preventing materials (sediment, nutrients, toxins, etc.) from entering a stream depends upon on its continuity in addition to its width, particularly when it is narrow (Weller et al. 1998). Consequently, riparian reserves in critical habitat reaches should be continuous. In open landscapes, such as agricultural fields, vegetation from reserve areas will collect windblown insects (Whitaker et al. 2000). Such insects, falling from riparian vegetation into the water constitute an important food source in headwater streams (Allan et al. 2003; Schlosser 1991).More than 30 m of riparian vegetation may be required for full mitigation of warming (Brown & Krygier 1970; Castelle et al. 1994; Lynch et al. 1984), and siltation (Davies & Nelson 1994; Kiffney et al. 2003; Moring 1982), and for long-term maintenance of channel morphology (Murphy et al. 1986; Murphy & Koski 1989). At least 10 m are required to maintain levels of terrestrial food inputs similar to those of forested landscapes (Culp & Davies 1983). Reserves as narrow as 5 m provide significant protection from bank erosion and sediment deposition from overland flow (Lee et al. 2003; McKergow et al. 2003).

Failure to maintain an adequate riparian reserve as part of critical habitat is highly likely to cause population-level impacts. In habitats lacking sufficient flow or groundwater sources, lack of shade may increase water temperatures to harmful levels. Increased erosion due to poorer bank stability will cause sediment deposition in riffles, impairing spawning and incubation, and reducing food availability. Nutrient loading will be higher in reaches without adequate riparian vegetation (Dhondt et al. 2002; Lee et al. 2003; Martin et al. 1999) and is likely to contribute to hypoxia through eutrophication. Solar radiation will also be higher in reaches lacking adequate riparian shading (Kiffney et al. 2003) and will contribute to eutrophication and hypoxia.

Width required to protect key habitat attributes for Salish sucker have not been quantified. They favour benthic over drifting invertebrates (Scott & Crossman 1973) suggesting they are less dependant on insects of terrestrial origin than salmonids. Salish suckers also appear tolerant of slightly higher water temperatures and lower oxygen levels than salmonids. Adults inhabit larger, deep pools with abundant cover within the stream, usually in association coho salmon (Pearson 2004). This suggests that they are equally dependant on large woody debris supply and natural channel movement, dominant forces in the creation of such pools in streams (Bilby & Bisson 1998; Gurnell et al. 2002). As riffle spawners and benthic insectivores they are likely similarly or more vulnerable to sedimentation impacts than salmonids are. Overall, there is no reason to believe that Salish sucker require narrower buffers than salmonids.

BC MOE and DFO have already developed and implemented a methodology for determining riparian reserve widths required to protect fish habitat in streams. The Riparian Area Regulation (RAR) was developed under the *Fish Protection Act* to protect "salmonids, game fish, and regionally significant fish" from the impacts of land development. In the absence of definitive data for a *SARA* listed species, this seem to be a very reasonable standard to apply in the identification of PCH, and forms the basis of the methodology employed (see below).

Finally, it should be noted that riparian reserve strips upstream of PCH reaches are important in minimizing sedimentation and other impacts within PCH. For this reason stewardship programs should promote the establishment of riparian reserve strips of native vegetation throughout the watershed, not just along PCH reaches.

Amount of Critical Habitat Required

The amount of critical habitat required to meet a recovery target needs to be based on population targets derived from credible area-abundance relationships or, ideally, robust population viability analyses (Rosenfeld & Hatfield 2006). Unfortunately the necessary demographic data for population viability analysis are lacking for Salish sucker and area-abundance relationships remain highly uncertain. In these circumstances, an appropriate guideline for minimum viable population (MVP) must be estimated from values for other species. Based on an extensive review of the scientific literature (Reed et al. 2003; Thomas 1990), mean MVP for vertebrate species is approximately 7300 breeding adults (median = 5800; n =102; range 2000-10000). From these data an abundance of reproductive adults in the low to mid thousands is considered adequate to maintain genetic diversity and to buffer the population from random variations in survival, and thus to maintain long-term viability in the absence of deterministic factors causing the population to decline.

Populations of Salish sucker in each of the ten watersheds are essentially independent of one another, with low probability of natural exchange of individuals between watersheds because there are little or no aquatic linkages between them or because they are separated the large distances of unsuitable habitat (Pearson, 2004). Natural recolonization of a watershed from which a population has been extirpated (rescue effect) is unknown but likely of low probability. Each watershed, consequently, warrants a separate recovery target in the low to mid thousands.

The amount of PCH required is a function of population density. Pearson (2004) estimated density of adult Salish suckers at 88 sites using a CPUE –density relationship developed by mark-recapture studies at four sites in three watersheds. Density was very low at three of the sites, but the fourth (Pepin Brook) contained an extraordinarily high density of Salish suckers. The site was repeatedly sampled for two years (Pearson and Healey, 2003; Pearson 2004) yielding a mean CPUE of 7.8 fish per trap (n= 521), by far the highest of the 88 sites sampled for Salish sucker during this period[2]. Among other sites, estimated density of Salish sucker ranged from 0 to 0.22 fish/m^2, and exceeded .05 fish/m^2 at only 7 sites (Pearson 2004). Assuming that a healthy population density in good habitat was in the range of 0.05 to 0.20 adults per m^2, approximately 36,500 to 146,000 m^2 of deep pool habitat would be required to support an MVP of 7300. Total available deep pool habitat in reaches identified as PCH is within or somewhat below this upper range in all watersheds (Table 4) suggesting that all PCH should be protected as critical habitat under *SARA*. Population estimates for some of these watersheds were made in 1999-2002 and are provided in Table 5. Based on these current observed densities of fish, the upper confidence levels of all but one of the populations are below the lower limit of the MVP estimate for vertebrates, and the estimated means of all are well below this limit.

The estimated carrying capacity of habitat calculated based on 0.05 and 0.20 adults per m2 (Table 4) can be viewed as lower and upper bounds on adult population size if all PCH is occupied. However, few sampled sites actually had densities within this range, and much of the PCH is unoccupied (effective density of zero) and potentially of low habitat quality. This means that in the absence of any improvement in habitat quality (=fish density) the capacity estimated using 0.05 fish per m^2 (see Table 4) is likely most realistic, and current and future sucker populations can therefore be expected to remain largely below the threshold average MVP for vertebrates even if all PCH is protected.

In addition to the population-based criteria above, the quantity of critical habitat required can also be based on the listing criteria, and the recovery goals and objectives for the species. Salish Sucker were listed because of a limited number of population and loss of habitat. All existing occupied habitat is therefore required to move the species towards delisting. Recovery goals in the Recovery Strategy also explicitly require self-sustaining populations throughout their native distribution, which requires populations that are likely to persist without dependence on rescue from another population. Multiple populations are required to increase the probability of a rescue effects (i.e. should a population be extirpated due to a chemical spill into a stream that does no long-term habitat damage), but the rescue effect cannot be effective if habitat in a population is allowed to degrade and a population declines in size so that is demographically vulnerable to stochastic extinction.

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[2] Unfortunately, abundance in the reach crashed to near zero in 2003 due to extreme hypoxia.

Table 4: Length of potential critical habitat (PCH), the area of deep pool habitat within it, its estimated carrying capacity for Salish suckers and the amount of PCH currently occupied. Carrying capacity estimates assume good habitat quality throughout and are estimated under two density scenarios and rounded to nearest hundred (adapted from Pearson 2004 and unpubl. data).

Watershed	**Total PCH (km)**	**Area of Deep Pool in PCH Reaches (m^2)**	**Estimated 'Carrying Capacity' of PCH (Number of adults) under two density scenarios**		**PCH Occupied (km)**
			0.05/m²	***0.20/m²***	
Agassiz Slough	5.6	39,200	2,000	7,800	<1
Chilliwack delta	28.0	140,000	7,000	28,000	<16
Bertrand Creek	7.9	16,100	800	3,200	unknown
Fishtrap Creek	8.3	94,600	4,700	18,900	unknown
Miami Creek	7.4	30,000	1,500	6,000	<1.8
Mountain Slough	9.1	45,500	2,300	9,100	<4.6
Pepin Creek	10.2	24,000	1,200	4,800	<6.5
Upper Salmon River*	unknown	35,800	1,800	7,200	unknown
Salwein Creek/ Hopedale Slough	8.3	53,900	2,700	10,800	<2.5

*Applies only to the main stem upstream of 248th Street.

Table 5: Population estimates for watersheds containing Salish sucker in Canada. Estimates are sums of reach scale estimates calculated from catch-per-unit effort (CPUE) data. CPUE was too low to allow estimation in four watersheds. Minimum and maximum values are calculated from the lower and upper confidence intervals of CPUE-density relationship (from Pearson, 2004).

	Population Estimate		
Watershed	Mean	Minimum	Maximum
Salmon River	1390	650	3580
Bertrand Creek	240	100	670
Pepin Brook	2860	1990	9200
Fishtrap Creek	490	210	1370
Salwein Creek	1290	550	3580
Miami Creek	850	350	2480
Hopedale Slough	?	?	?
Atchelitz/Chilliwack	?	?	?
Mountain Slough	?	?	?
Agassiz Slough	?	?	?

Activities Likely to Destroy Critical Habitat for Salish sucker

SARA requires that activities likely to result in the destruction of critical habitat be listed and described. Table 3 provides this information for Nooksack dace.

Table 6: Activities likely to result in destruction of potential critical habitat for Salish sucker.

Activity	Result
Over application of Fertilizer	Nutrient loading of streams through excessive application of manure is the most common cause of the chronic late summer hypoxia that affects many reaches inhabited by Salish sucker (Schreier et al., 2003).
Drainage projects	Dredging, dyking, and channelization works directly destroy habitat, cause sediment deposition in riffles, and reduce base flow,
Urban storm drainage	Storm drain systems that discharge directly to creeks are major sources of toxic contamination and sediment. They also reduce baseflow by inhibiting water infiltration to aquifers.
Riparian vegetation removal	Loss of riparian vegetation exposes a stream to increased erosion and sediment deposition, elevated water temperatures, reduced supplies of terrestrially derived food, and increased nutrient loading
Livestock access to creeks	Livestock damage habitat by trampling or causing erosion that clogs riffles with sediment. Access also contributes to nutrient loading.
Excessive water withdrawal	Water extraction (surface or ground) during dry periods reduces flows, which may contribute to hypoxia and drying of riffles needed for spawning.
Excessive sediment releases	Sediment deposition in spawning substrate and inhibition of the flow of oxygen-rich water to eggs and larvae during incubation.

Activity	Bertrand Creek	Pepin Brook	Fishtrap Creek	Upper Salmon River	Salwein/ Hopedale Slough	Atchelitz/ Chilliwack/ Semmihault	Miami Creek	Mountain Slough	Agassiz Slough	Elk Creek/ Hope River
Over application of l fertilizer	+++	++	+++	+++	++	+++	+++	+++	++	+++
Drainage projects	++	+	+++	++	++	+++	+++	+++	+	+++
Urban storm drainage	+++	-	+++	-	-	+++	++	-	+++	++
Riparian vegetation removal	++	+	+++	++	+++	+++	+++	+++	++	++
Livestock access to creeks	+	+	+	++	++	++	++	++	+	++
Excessive water withdrawal	+++	+	++	+++	+	++	++	++	++	++
Excessive sediment releases	+	+++	++	+	+	++	+	+++	+	+

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+++	major concern	+	minor concern
++	moderate concern	-	not a concern

Assessment of Riparian Reserve Widths in Potential Critical Habitat

Methods

Overview

Three aspects of potential riparian critical habitat were assessed at the reach scale:

1. The extent of existing riparian vegetation.
2. The width of riparian reserve required in PCH for Salish sucker and/or Nooksack dace.
3. The length of bank in PCH reaches where riparian reserve width or integrity is restricted by permanent structures.

Assessments were made using a GIS-based adaptation of the British Columbia Riparian Area Regulation (RAR) Assessment Methods. The few changes made accommodate differences from the scale or intent of RAR assessments. In scale, the current assessment covers large portions of 11 lowland watersheds rather than individual land parcels for which the RAR is intended. The intent is to provide a basis for the protection and restoration of critical habitat under existing adjacent land uses rather than to secure riparian habitat during a change in adjacent land use as in an RAR assessment.

Mapping Methods

Potential critical habitat reaches were mapped on high-resolution colour orthophotographs (2004, pixel size = 0.25 m on ground) of the 11 watersheds known to contain Salish sucker and/or Nooksack dace populations using a Geographic Information System (ArcView 9.1, ESRI Canada). Each reach was delineated by three lines, a central one representing the aquatic habitat, flanked by two lines representing the riparian reserve required on each bank. These are drawn at approximately the top of bank[3]. The riparian reserve lines were used to construct additional overlay lines to measure the length of bank associated with each category of riparian reserve width, the width of existing riparian vegetation, and the length of PCH in which permanent structures restrict riparian reserve width. As output from a GIS system, the mapped lines are those actually measured to generate the data. They are fully georeferenced and compatible with the GIS systems used in the planning and engineering departments of most local governments.

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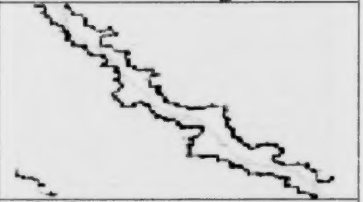
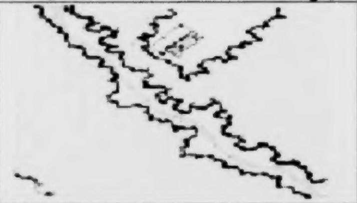
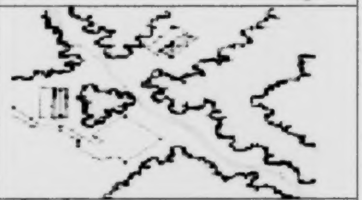
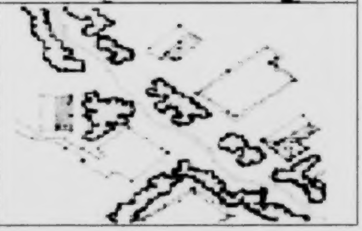
[3] Parcel-specific surveys using standard RAR assessment methods are required to determine the location of top of bank and riparian reserve boundaries on the ground.

Existing riparian vegetation[4]

The current state of native riparian vegetation in sections of each reach (minimum length = 100 m) was assigned to one of four categories based on its width and continuity (Table 7).

Table 7: Categories of existing riparian vegetation. Adapted from the British Columbia Riparian Area Regulation Assessment Methods (Anonymous 2005).

Category	Description	Drawing
50	Intact and continuous areas of existing vegetation equal or greater than 50 m wide	
30	Limited but continuous areas of existing vegetation equal to 30 metres wide or discontinuous but occasionally wider areas of existing vegetation between 30 and 50 m wide.	
15	Narrow but continuous areas of existing vegetation equal to 15 metres wide or existing vegetation between 15 and 30 m wide.	
5	Very narrow but continuous areas of existing vegetation up to 5 metres wide or discontinuous but occasionally wider areas of existing vegetation between 5 and 15 metres wide interspersed with permanent structures.	

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[4] The RAR methods assess '*existing or potential* streamside vegetation conditions' as a single entity. In this adaptation of it, only existing vegetation is included. There are two reasons for this. First, an inventory of existing vegetation allows estimation of the extent of riparian restoration required. This is key data for recovery planning that is not required for RAR purposes. Second, assessment of potential riparian vegetation requires a full field assessment at the site (land parcel) scale to accurately map the limitations imposed by permanent structures and human activities.

Width of Riparian Reserve[5]

The width of riparian reserve in a PCH reach is equivalent to the widest zone of sensitivity (ZOS) calculated for each of 5 riparian features, functions and conditions: large woody debris supply for fish habitat and maintenance of channel morphology, localized bank stability, channel movement, shade, and insect and debris fall. The ZOS for each function, in turn, depends on the state of two or three contributing factors. For example, the ZOS for shade depends on channel width, channel orientation, and the late seral vegetation type (tree, shrub, grass) expected for a reach. The contributing factors and decision rules used to calculate ZOS values for each riparian function are given in Table 8.

Channel width was measured on the digital ortho-photos for reaches wider than 10 m with clearly visible banks. All others were taken from Pearson (1998 or unpublished thesis data) or measured in the field. Channel morphology of most reaches fitted the pool-riffle category of the RAR assessment method. Reaches comprised of slough, pond, or permanent wetland with a channel width exceeding 30 m were placed in the "Slough' category and assigned a ZOS of 15 m for large woody debris, fish habitat and rooted vegetation, as lakes and wetlands are under the RAR methodology.

Permanent structures restricting Riparian Reserve Width

Riparian reserves are commonly restricted by permanent structures that limit potential vegetation development. The length of bank where permanent structures restrict riparian reserve width was measured and the type of structure assigned to one of the following categories:

- Building and associated yard
- Road
- Dyke
- Other water body
- Railway
- Private Road or driveway
- Public trail
- Fish fence

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[5] Identical to the RAR method's SPEA except that the ZOS for filtration is set as a constant at 5 m. The RAR sets stormwater infiltration criteria for new development within 30 m of the channel, an approach that could also be adopted for riparian reserve areas.

Table 8: Decision rules for establishing the zone of sensitivity (ZOS) for riparian functions. Width of the riparian reserve included in potential critical habitat is equivalent to the widest ZOS value for a function. The lower table provides codes and definitions for contributing factors, and variables used in ZOS calculations. Adapted from BC Riparian Area Regulation Assessment Methods (Anonymous 2005).

Function(s) (contributing factors)	**Zone of sensitivity (ZOS; m)**	**Maximum ZOS (m)**	**Minimum ZOS (m)**
Shade	3 when RPVT = LC	5 when RPVT = SH	
(RPVT, CO, CW)	2 x CW on south bank when RPVT = SH and CO=B,	15 when CO = A	
	1 x CW when RPVT = SH otherwise	10 on north bank when CO = B or C	
	3 x CW on south bank when RPVT = TR and CO = B,	15 on south bank when CO = C	
	2 x CW when SPVT = TR otherwise	30 on south bank when CO=B	
Large woody debris	15 m when CM = SL	5 m when RPVT=LC	
Area for localized bank stability	3 x channel width when CM = RP	20 m when RPVT = SH	
Area for channel movement	2x channel width when CM = CP	30 m when RPVT = TR	
(CM, RPVT)			
Food and nutrients	5 when RPVT = LC	15 when RPVT = SH	5 when RPVT = SH
(RPVT, CW)	2 x CW when RPVT = SH	15 when RPVT = TR	10 when RPVT = TR
	3 x CW when RPVT = TR		

Code	**Variable/Level**	***Definition***
A	North-South	A level of the channel orientation (CO) variable (Figure 2)
B	East-West	A level of the channel orientation (CO) variable (Figure 2)
C	Other	A level of the channel orientation (CO) variable (Figure 2)
CM	Channel morphology	Type defined by characteristic ranges in slope, relative roughness, relative depth, bank stability, and channel stability (e.g. pool-riffle morphology)
CO	Channel orientation	The approximate orientation of the reach (see Fig. 2). Channel orientation may be combined for a reach (e.g. AC).
CP	Cascade-pool	A cascade-pool channel characterized by cobble-boulder substrate and moderate slope. (related to width but less than 6.5 %, Anonymous 2005), A level of the CM (channel morphology) variable.
CW	Channel width	Average distance between top of bank on the left and right banks in the reach.
LC	Low cover	Low ground cover (grass, sedge etc.) A level of the RPVT (reach potential vegetation type) variable.
RP	Riffle –pool	A riffle-pool channel characterized by gravel- cobble substrate and gentle slopes (related to width but less than 4 %, Anonymous 2005). A level of the CM (channel morphology) variable.
RPVT	Reach Potential Vegetation Type	The mature seral stage of riparian vegetation. In most areas, the value will be TR (trees). Shrub (SH) or low ground cover (LC) values may occur due to frequent natural disturbances.
SH	Shrub	Deciduous or coniferous shrubs. A level of the RPVT (reach potential vegetation type) variable.
SL	Slough	A slough channel characterized by silty substrates, zero slope, and a channel width (CW) greater than 30 m
TR	Tree	Deciduous or coniferous trees. A level of the RPVT (reach potential vegetation type) variable.

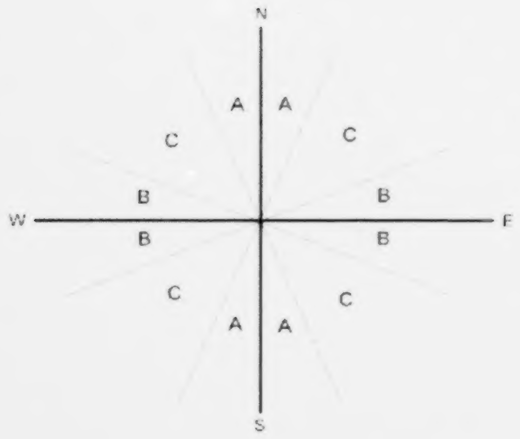


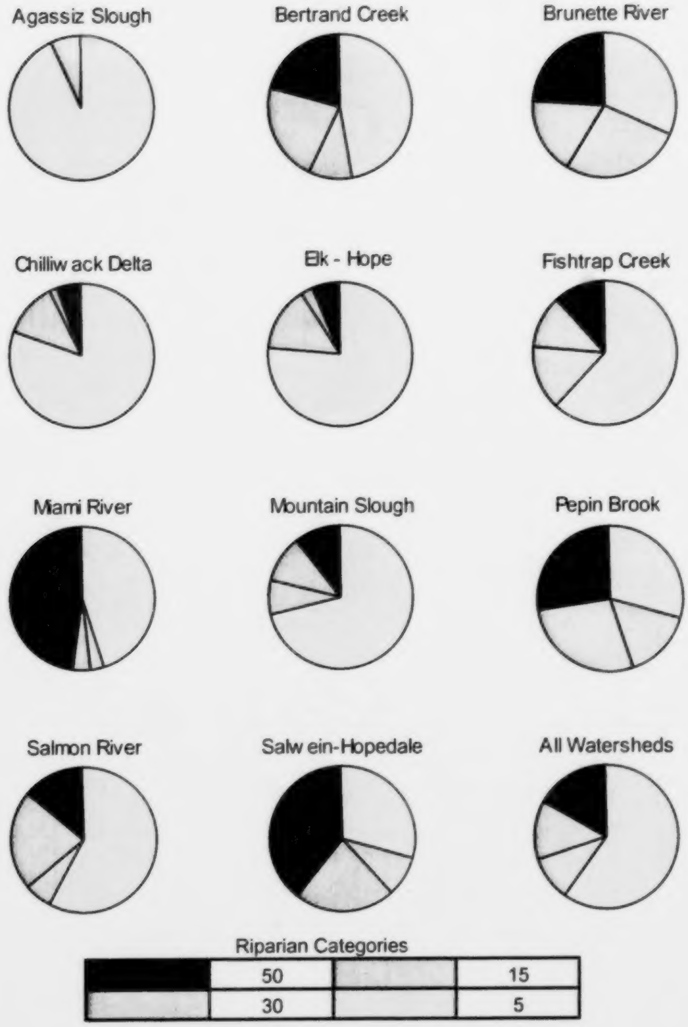
Figure 2: Stream orientation zones for establishing the zone of sensitivity (ZOS) for shade (for use with Table 4).

Results and Discussion

Existing Riparian Vegetation

The condition of existing riparian vegetation varies widely among watersheds. In a few, notably the Miami River and Salwein Creek/Hopedale Slough, PCH reaches run through relatively large blocks of intact forest (Fig. 3.). Fully 60% (197.6 km) of PCH, however, currently supports less than 5 m of continuous riparian vegetation. Figure 4 shows existing riparian vegetation on the PCH reaches of Agassiz Slough. Similar maps for the remaining watersheds are provided in Appendix 1.

Increasing the width and continuity of native riparian reserve strips in PCH is identified as a high priority in the recovery strategies for both species. Its current impoverished state justifies and adds urgency to that strategy. The maps generated are also proving useful in identifying and prioritizing reaches for riparian enhancement.


Agassiz Slough

Bertrand Creek

Brunette River

Chilliwack Delta

Elk - Hope

Fishtrap Creek

Miami River

Mountain Slough

Pepin Brook

Salmon River

Salwein-Hopedale

All Watersheds

Figure 3: Proportion of potential critical habitat (by bank length) bordered by riparian vegetation of differing width categories (see Table 1 for definitions).

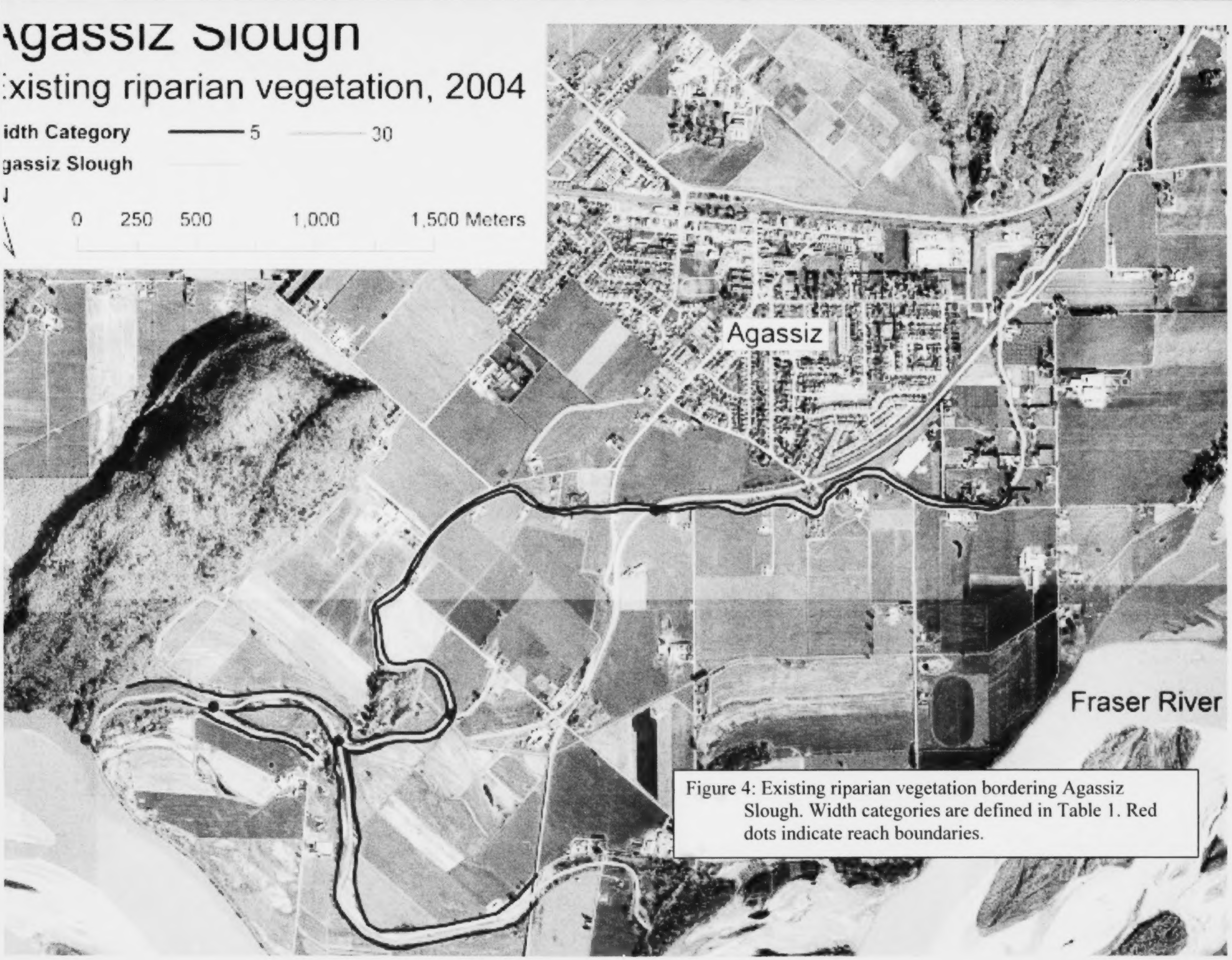

gassiz Slough
xisting riparian vegetation, 2004
idth Category
5
30
gassiz Slough
0
250
500
1,000
1,500 Meters
Agassiz
Fraser River

Figure 4: Existing riparian vegetation bordering Agassiz Slough. Width categories are defined in Table 1. Red dots indicate reach boundaries.

Riparian Reserve Widths

Calculated Widths

Across the range of both species, a total area of 716.6 ha was identified riparian reserve (Table 9). Its width averaged 21.4 m (s. dev. = 6.77) for the 140 reaches encompassing all identified PCH for both species. Widths between 25 and 30 m were assessed for 40% of PCH length, while widths less than 10 m were assessed for less than 3% of length (Table 9). The minimum value of 5 m was associated with a single reach (MTN1) at the confluence of Mountain Slough and the Fraser River, where the natural riparian vegetation is grass, which minimizes ZOS values for all functions.

Table 9: Total area and length of riparian reserve strips included in potential critical habitat for Salish sucker and/or Nooksack dace. Reach widths were rounded up to the nearest width category.

Watershed	**Length (km) in Width Category (m)**						**Total Length (km)**	**Total Area (ha)**
	5	**10**	**15**	**20**	**25**	**30**		
Agassiz Slough			5.30			9.79	15.09	35.9
Bertrand Creek			7.90	7.48	9.48	13.07	37.93	83.7
Brunette River		5.09	10.43	0.00	0.00	7.36	22.87	37.3
Chilliwack Delta			19.82	11.78	16.95	16.89	65.43	142.2
Elk-Hope			25.20			22.03	47.22	101.8
Fishtrap Creek		2.07	5.98	2.58	4.32	6.99	21.94	47.7
Miami River			5.02	2.88		7.63	15.53	34.3
Mountain Slough	1.03		5.56	10.37		2.61	19.58	36.4
Pepin Brook		0.52	12.75	3.00		7.02	23.29	43.2
Salmon River			2.01	3.50	3.92	30.36	39.79	107.7
Salwein - Hopedale			3.57	2.21	3.51	10.42	19.71	46.3
Total	1.03	7.67	103.54	43.79	38.18	134.16	328.37	716.6
% Total	0.3	2.3	31.5	13.3	11.6	40.1		

Permanent structure restrictions

The width of riparian reserve is restricted, to some extent, by permanent structures over 106.3 km (32%) of its length (Table 10). The proportion of length affected varies widely by watershed. Agassiz Slough is most affected, with riparian reserve width restricted by roads, dykes and buildings in over 80% of its PCH. Conversely, less than 10% of riparian PCH length is affected in Pepin Brook (Figure 5). The extent of restriction on riparian reserve width imposed by these structures varies from complete to slight, but can only be assessed reliably on a site-specific basis. Negotiations with landowners or regulators may also ease restrictions (e.g. through planting in residential yards, or on road embankments). Riparian reserve width and the portions of its length where width is restricted by permanent structures are shown for Agassiz Slough in Figure 6. Similar maps for the other 10 watersheds included in this assessment are provided in Appendix 1.

Table 10: Length (km) of potential critical habitat in each watershed where various type of permanent structure restrict riparian reserve width.

Watershed	Building	Road	Private road	Dyke	Rail	Trail	Waterbody	Fish fence	Total
Agassiz Slough	0.84	7.01	2.46	2.75					13.06
Bertrand Creek	4.34	0.67	1.65			0.05			6.71
Brunette	1.97	4.81	0.21		0.19	2.18			9.35
Chilliwack Delta	16.54	7.39	2.60		0.15				26.68
Elk-Hope	7.52	12.50	0.97		0.05	0.29			21.33
Fishtrap Creek	5.83	1.91	0.46			0.12			8.33
Miami River	3.69	0.42		0.09					4.20
Mountain Slough	0.96	0.32	0.40	1.02	0.06				2.76
Pepin Brook	0.05	0.92	0.85			0.08			1.90
Salmon River	0.97	2.62	2.05	0.06	0.12		0.73	0.02	6.58
Salwein-Hopedale		3.04		2.06	0.03	0.03	0.27		5.43
Total	42.72	41.60	11.66	5.99	0.60	2.75	1.00	0.02	106.33

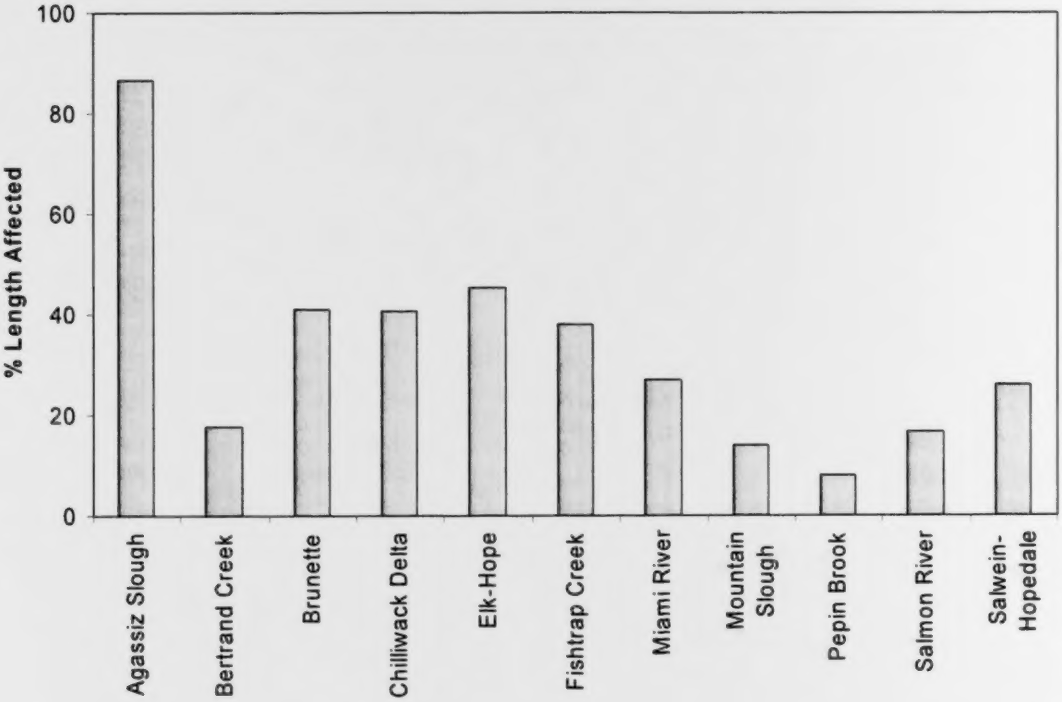


Figure 5: Proportion of potential critical habitat (by length) in each watershed where permanent structures restrict the width of riparian reserve.

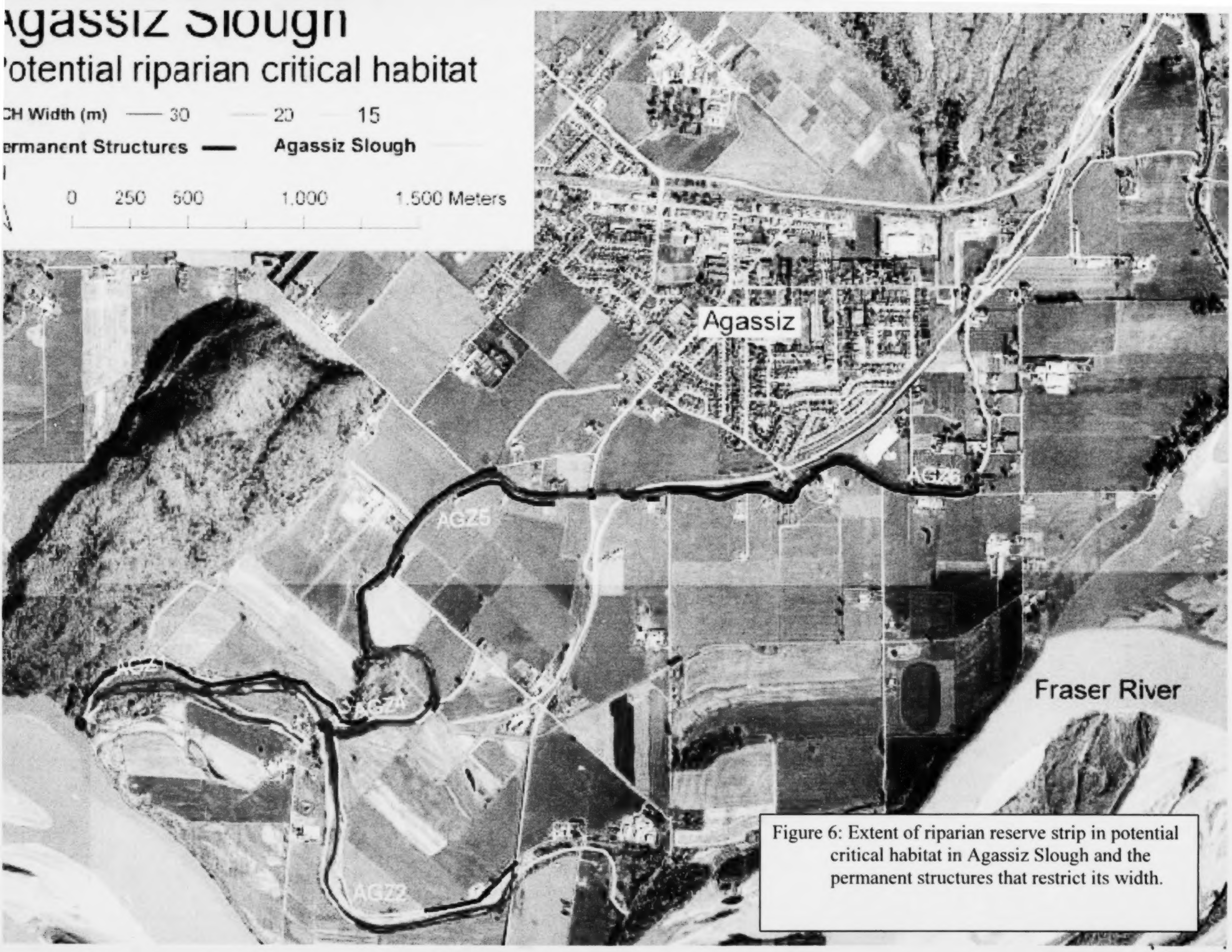

gassiz Slough
otential riparian critical habitat
H Width (m) 30 20 15
ermanent Structures
Agassiz Slough
0 250 500 1,000 1,500 Meters
Agassiz
AGZ6
AGZ5
AGZ1
AGZ4
AGZ2
Fraser River

Figure 6: Extent of riparian reserve strip in potential critical habitat in Agassiz Slough and the permanent structures that restrict its width.

Conclusions

The potential critical habitat for Salish sucker and Nooksack dace was defined using reach-scale, in-stream habitat characteristics. It comprises 166 km of channel and 328 km of bank in140 reaches and 11 watersheds. It includes riparian reserve strips along each bank. Their width was assessed using an adaptation of British Columbia's Riparian Area Regulation assessment methodology. It extends laterally from the top of bank along both banks of the full length of each potential critical habitat reach to a distance equal to the widest zone of sensitivity (ZOS) calculated for each of 5 riparian features, functions and conditions: large woody debris supply for fish habitat and maintenance of channel morphology, localized bank stability, channel movement, shade, and insect and debris fall. Widths range from 5 to 30 m, with an average of 21.4 m (s. dev = 6.77) and total area encompasses 717 ha of land.

Existing riparian vegetation is sparse, with 60% of bank length supporting discontinuous bands of vegetation less than 5 m wide, a fact that highlights the need for recovery activities focused on riparian enhancement and restoration. Permanent structures such as roads, farm crossings, buildings, and yards restrict the width of riparian reserve strips along 106 km (32%) of PCH length to less than its calculated value. Securing riparian reserve strips through purchase, lease, or easement should be a priority for conserving these species. Such a program would, provide benefits to a number of other SARA listed species, in addition to salmonids, surface water quality, and agricultural drainage.

Literature Cited

Allan, J. D. 2004. Landscapes and riverscapes: The influence of land use on stream ecosystems. Annual Review of Ecology and Systematics **35**:257-284.

Allan, J. D., M. S. Wipfli, J. P. Caouette, A. Prussian, and J. Rodgers. 2003. Influence of streamside vegetation on inputs of terrestrial invertebrates to salmonid food webs. Canadian Journal of Fisheries and Aquatic Science **60**:309-320.

Anonymous. 2005. Assessment methods (Riparian area regulation). British Columbia Ministry of Environment, Victoria.

Bilby, R. E., and P. A. Bisson. 1998. Function and distribution of large woody debris. Pages 324-346 in S. Kantor, editor. River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. Springer, New York.

Brown, G. W., and J. T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resources Research **6**:1133-1139.

Castelle, A. J., A. W. Johnson, and C. Conolly. 1994. Wetland and stream buffer size requirements - A review. Journal of Environmental Quality **23**:878 - 882.

COSEWIC. 2007. COSEWIC assessment and update status report on the Nooksack dace *Rhinichthys cataractae* ssp. in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. vii + 27pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Culp, J. M., and R. W. Davies. 1983. An assessment of the effects of streambank clear-cutting on macroinvertebrate communities in a managed watershed. Canadian Technical Reports on Fisheries and Aquatic Science **1208**:115 p.

Davies, P. E., and M. Nelson. 1994. Relationships between riparian buffer widths and the effects of logging on stream habitat, invertebrate community composition and fish abundance. Australian Journal of Marine and Freshwater Research **45**:1289-1305.

Dhondt, K., P. Boeckx, O. Van Cleemput, G. Hofman, and F. de Troch. 2002. Seasonal groundwater nitrate dynamics in a riparian buffer zone. Agronomie (Paris) **22**:747-753.

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management **10**:199-214.

Gurnell, A. M., H. Piegay, F. J. Swanson, and S. V. Gregory. 2002. Large wood and fluvial processes. Freshwater Biology **47**:601-619.

Imhof, J. G., J. Fitzgibbon, and W. K. Annable. 1996. A hierarchical evaluation system for characterizing watershed ecosystems for fish habitat. Canadian Journal of Fisheries and Aquatic Science **53 (Suppl. 1)**.

Inglis, S., S. M. Pollard, and M. L. Rosenau. 1994. Distribution and habitat of Nooksack dace (*Rhinichthys sp.*) in Canada. Regional Fisheries Report, B.C. Ministry of Environment, Lands and Parks, Surrey.

Kiffney, P. M., J. S. Richardson, and J. P. Bull. 2003. Response of periphyton and insects to experimental manipulation of riparian buffer width along forest streams. Journal of Applied Ecology **40**:1060-1076.

Lee, K. H., T. M. Isenhart, R. C. Schultz, and S. K. Mickelson. 2003. Multispecies riparian buffers trap sediment and nutrients during rainfall simulations. Journal of Environmental Quality **29**:1200-1205.

Lynch, J. A., G. B. Rishel, and E. S. Corbett. 1984. Thermal alteration of streams draining clearcut watersheds: Quanifications and biological implications. Hydrobiologia **111**:161-169.

Martin, T. L., N. K. Kaushik, J. T. Trevors, and H. R. Whiteley. 1999. Review: denitrification in temperate climate riparian zones. Water, air and soil pollution **111**:171-186.

McKergow, L. A., D. M. Weaver, I. P. Prosser, R. B. Grayson, and A. E. G. Reed. 2003. Before and after riparian management: Sediment and nutrient exports from a small agricultural catchment, Western Australia. Journal of Hydrology.

McPhail, J. D. 1997. Status of the Nooksack dace, *Rhinichthys sp.*, in Canada. Canadian Field Naturalist **111**:258-262.

Moring, J. R. 1982. Decrease in stream gravel permeability after clear-cut logging: an indication of intragravel conditions for developing salmonid eggs and alevins. Hydrobiologia **88**:295-298.

Murphy, M. L., J. Heifetz, S. W. Johnson, K. V. Koski, and J. F. Thedinga. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. Canadian Journal of Fisheries and Aquatic Science **43**:1521-1533.

Murphy, M. L., and K. V. Koski. 1989. Input and depletion of woody debris in Alaska streams and implications for streamside management. North American Journal of Fisheries Management **9**:427-436.

Pearson, M. P. 1998. Habitat inventory and enhancement needs for the endangered Salish sucker (*Catostomus sp.*) and Nooksack dace (*Rhinichthys sp.*). BC Ministry of Fisheries Project Report No. 76, Vancouver.

Pearson, M. P. 2004. The ecology, status, and recovery potential of Nooksack dace (*Rhinichthys cataractae* ssp.) and Salish sucker (*Catostomus* sp.) in Canada. Ph.D. thesis, University of British Columbia, Vancouver, Canada.

Pearson, M. P., T. Hatfield, J. D. McPhail, J. S. Richardson, J. S. Rosenfeld, H. Schreier, D. Schluter, D. J. Sneep, M. Stejpovic, E. B. Taylor, and P. M. Wood. 2007a. Recovery Strategy for Nooksack Dace (*Rhinichthys cataractae* ssp.) in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Vancouver. Fisheries and Oceans Canada.

Pearson, M. P., T. Hatfield, J. D. McPhail, J. S. Richardson, J. S. Rosenfeld, H. Schreier, D. Schluter, D. J. Sneep, M. Stejpovic, E. B. Taylor, and P. M. Wood. 2007b. Recovery Strategy for Salish sucker (*Catostomus* sp.) in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Vancouver. Fisheries and Oceans, Canada. ix+31 pp.

Pearson, M. P., and M. C. Healey. 2003. Life history characteristics of the endangered Salish sucker (*Catostomus sp.*) and their implications for management. Copeia **2003**:759-768.

Puckett, L. J. 2004. Hydrologic controls on the transport and fate of nitrate in ground water beneath riparian buffer zones: results from thirteen studies across the United States. Water Science and Technology **49**:47-53.

Reed, H. R., J. J. O'Grady, B. W. Brook, J. D. Ballou, and R. Frankham. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation **113**:23-34.

Rosenfeld, J., and T. Hatfield. 2006. Information needs for assessing critical habitat of freshwater fish. Canadian Journal of Fisheries and Aquatic Science **63**:683-698.

Schlosser, I. J. 1991. Stream fish ecology: A landscape perspective. BioScience **41**:704-712.

Scott, W. B., and E. J. Crossman 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Fisheries and Oceans Canada, Ottawa.

Stauffer, J. C., R. M. Goldstein, and R. M. Newman. 2000. Relationship of wooded riparian zones and runoff potential to fish community composition in agricultural streams. Canadian Journal of Fisheries and Aquatic Science **57**:307-316.

Thomas, C. D. 1990. What do real population dynamics tell us about minimum viable population sizes? Conservation Biology **4**:324-327.

Wehrly, K. E., M. J. Wiley, and P. W. Seelbach. 2003. Classifying regional variation in thermal regime based on stream fish community patterns. Transactions of the American Fisheries Society **132**:18-38.

Weller, D. E., T. E. Jordan, and D. L. Correll. 1998. Heuristic models for material discharge from landscapes with riparian buffers. Ecological Applications **8**:1156-1169.

Whitaker, D. M., A. L. Carroll, and V. A. Montevecchi. 2000. Elevated numbers of flying insects and insectivorous birds in riparian buffer strips. Canadian Journal of Zoology **78**:740-747.

Wigington, P. J., S. M. Griffith, J. A. Field, J. E. Baham, W. R. Horwath, J. Owen, J. H. Davis, S. C. Rain, and J. J. Steiner. 2003. Nitrate removal effectiveness of a riparian buffer along a small agricultural stream in western Oregon. Journal of Environmental Quality **32**:162-170.

Pearson, M. P. 2004. The ecology, status, and recovery potential of Nooksack dace (*Rhinichthys cataractae* ssp.) and Salish sucker (*Catostomus* sp.) in Canada. Ph.D. thesis, University of British Columbia, Vancouver, Canada.

Pearson, M. P., T. Hatfield, J. D. McPhail, J. S. Richardson, J. S. Rosenfeld, H. Schreier, D. Schluter, D. J. Sneep, M. Stejpovic, E. B. Taylor, and P. M. Wood. 2007a. Recovery Strategy for Nooksack Dace (*Rhinichthys cataractae* ssp.) in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Vancouver. Fisheries and Oceans Canada.

Pearson, M. P., T. Hatfield, J. D. McPhail, J. S. Richardson, J. S. Rosenfeld, H. Schreier, D. Schluter, D. J. Sneep, M. Stejpovic, E. B. Taylor, and P. M. Wood. 2007b. Recovery Strategy for Salish sucker (*Catostomus* sp.) in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Vancouver. Fisheries and Oceans, Canada. ix+31 pp.

Pearson, M. P., and M. C. Healey. 2003. Life history characteristics of the endangered Salish sucker (*Catostomus sp.*) and their implications for management. Copeia **2003**:759-768.

Puckett, L. J. 2004. Hydrologic controls on the transport and fate of nitrate in ground water beneath riparian buffer zones: results from thirteen studies across the United States. Water Science and Technology **49**:47-53.

Reed, H. R., J. J. O'Grady, B. W. Brook, J. D. Ballou, and R. Frankham. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation **113**:23-34.

Rosenfeld, J., and T. Hatfield. 2006. Information needs for assessing critical habitat of freshwater fish. Canadian Journal of Fisheries and Aquatic Science **63**:683-698.

Schlosser, I. J. 1991. Stream fish ecology: A landscape perspective. BioScience **41**:704-712.

Scott, W. B., and E. J. Crossman 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Fisheries and Oceans Canada, Ottawa.

Stauffer, J. C., R. M. Goldstein, and R. M. Newman. 2000. Relationship of wooded riparian zones and runoff potential to fish community composition in agricultural streams. Canadian Journal of Fisheries and Aquatic Science **57**:307-316.

Thomas, C. D. 1990. What do real population dynamics tell us about minimum viable population sizes? Conservation Biology **4**:324-327.

Wehrly, K. E., M. J. Wiley, and P. W. Seelbach. 2003. Classifying regional variation in thermal regime based on stream fish community patterns. Transactions of the American Fisheries Society **132**:18-38.

Weller, D. E., T. E. Jordan, and D. L. Correll. 1998. Heuristic models for material discharge from landscapes with riparian buffers. Ecological Applications **8**:1156-1169.

Whitaker, D. M., A. L. Carroll, and V. A. Montevecchi. 2000. Elevated numbers of flying insects and insectivorous birds in riparian buffer strips. Canadian Journal of Zoology **78**:740-747.

Wigington, P. J., S. M. Griffith, J. A. Field, J. E. Baham, W. R. Horwath, J. Owen, J. H. Davis, S. C. Rain, and J. J. Steiner. 2003. Nitrate removal effectiveness of a riparian buffer along a small agricultural stream in western Oregon. Journal of Environmental Quality **32**:162-170.

Appendix 1

An Assessment of Potential Critical Habitat for Nooksack Dace (*Rhinichthys cataractae* ssp.) and Salish Sucker (*Catostomus* sp.)

Watershed Scale Maps

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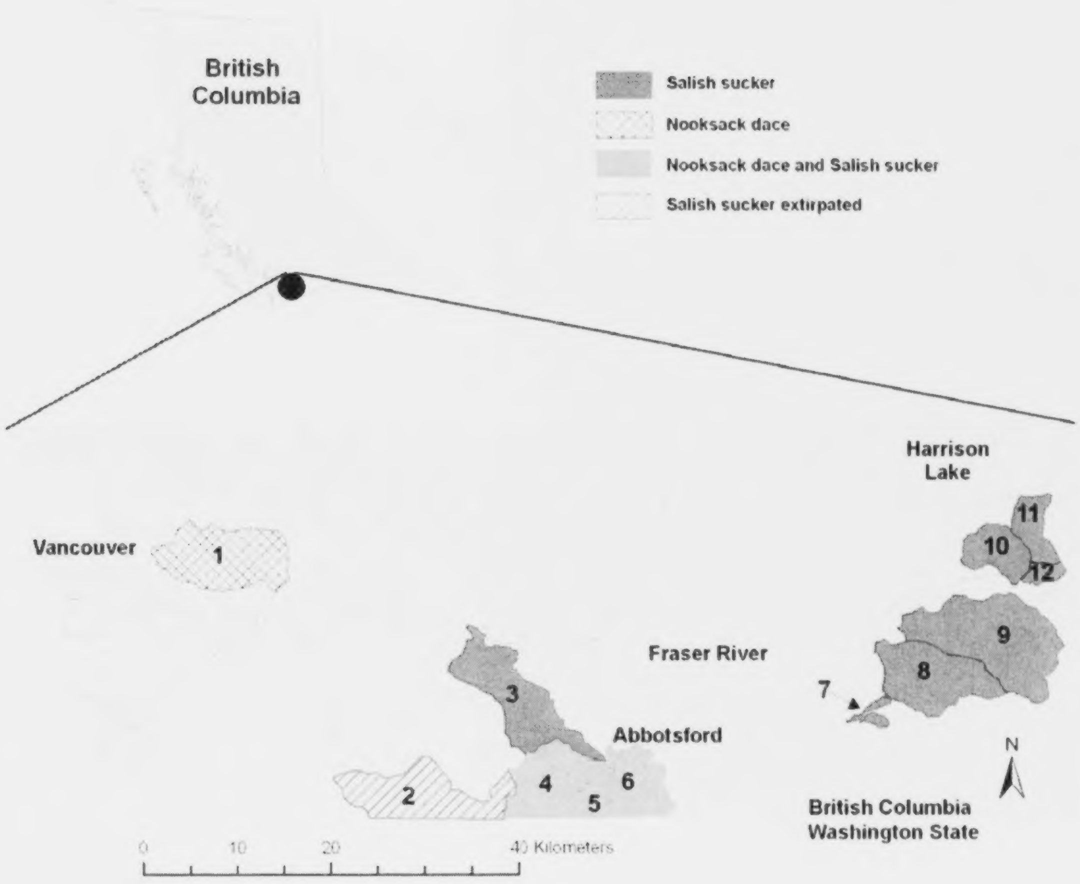
Introduction

This appendix the GIS watershed maps from which most of the data assessing potential riparian critical habitat (RCH) were generated. Table 1 describes the three categories of maps provided for each of the eleven watersheds included in the study.

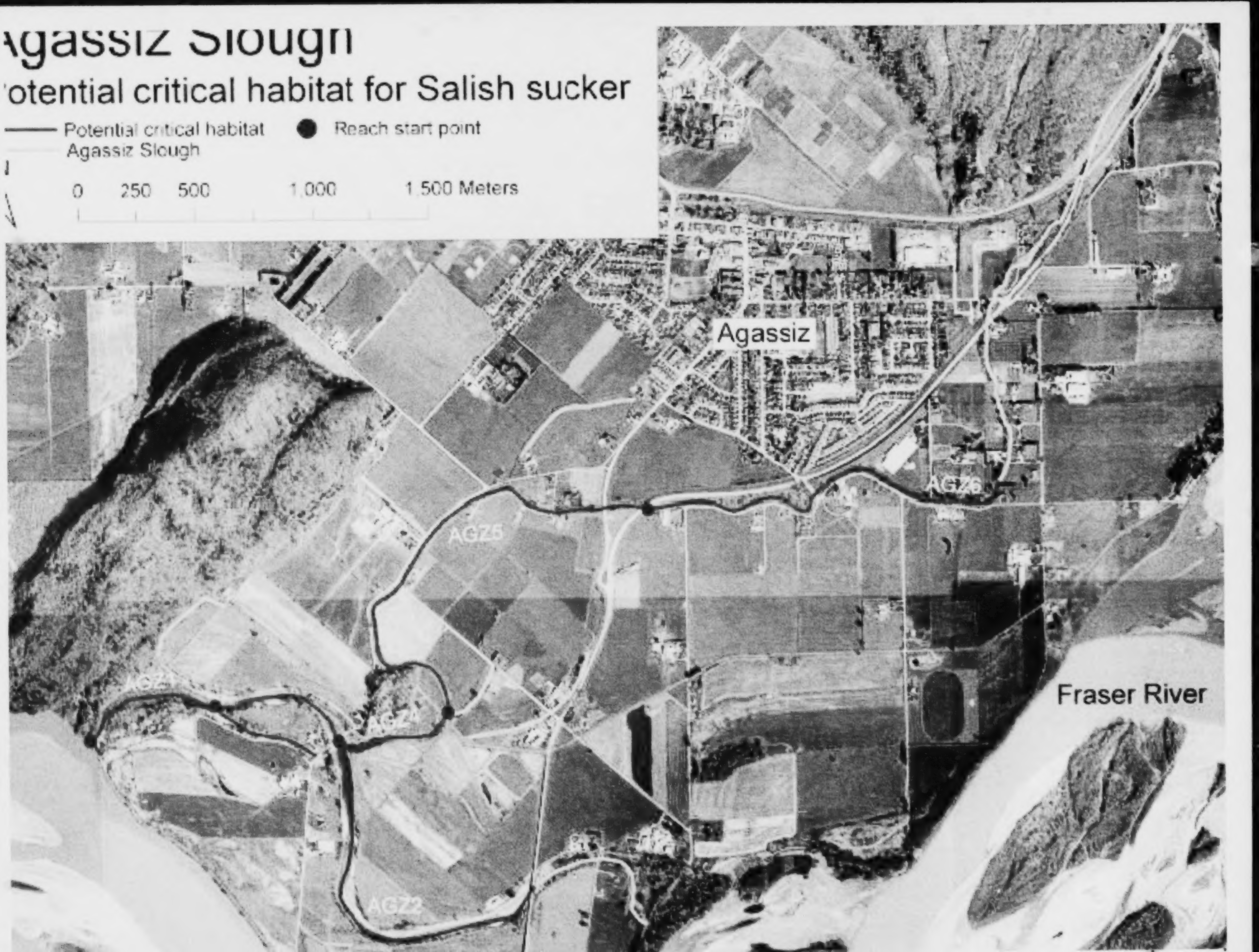
Table 1: Contents of the maps of each watershed included in this appendix.

Map	Shows
Critical habitat reaches	• Potential critical habitat reaches for Salish sucker or Nooksack dace.
Potential riparian critical habitat (RCH)	• Width categories of PRCH: the calculated width of native vegetation necessary to maintain full riparian function in each reach. Categories are in 5 m increments ranging from 5 m to 30 m.. • Portions of bank where RCH width is restricted by permanent structures.
Existing riparian vegetation	• Width categories of existing riparian vegetation as defined in Table 3 of the main document.


British Columbia
Salish sucker
Nooksack dace
Nooksack dace and Salish sucker
Salish sucker extirpated
Harrison Lake
Vancouver
1
11
10
12
9
Fraser River
8
7
3
Abbotsford
N
4
6
2
5
British Columbia
Washington State
0
10
20
40 Kilometers

1. Brunette River
2. Little Campbell River
3. Salmon River
4. Bertrand Creek
5. Pepin Brook
6. Fishtrap Creek
7. Salwein Creek/Hopedale Slough
8. Chilliwack Delta
9. Elk Creek/Hope River
10. Mountain Slough
11. Miami River
12. Agassiz Slough

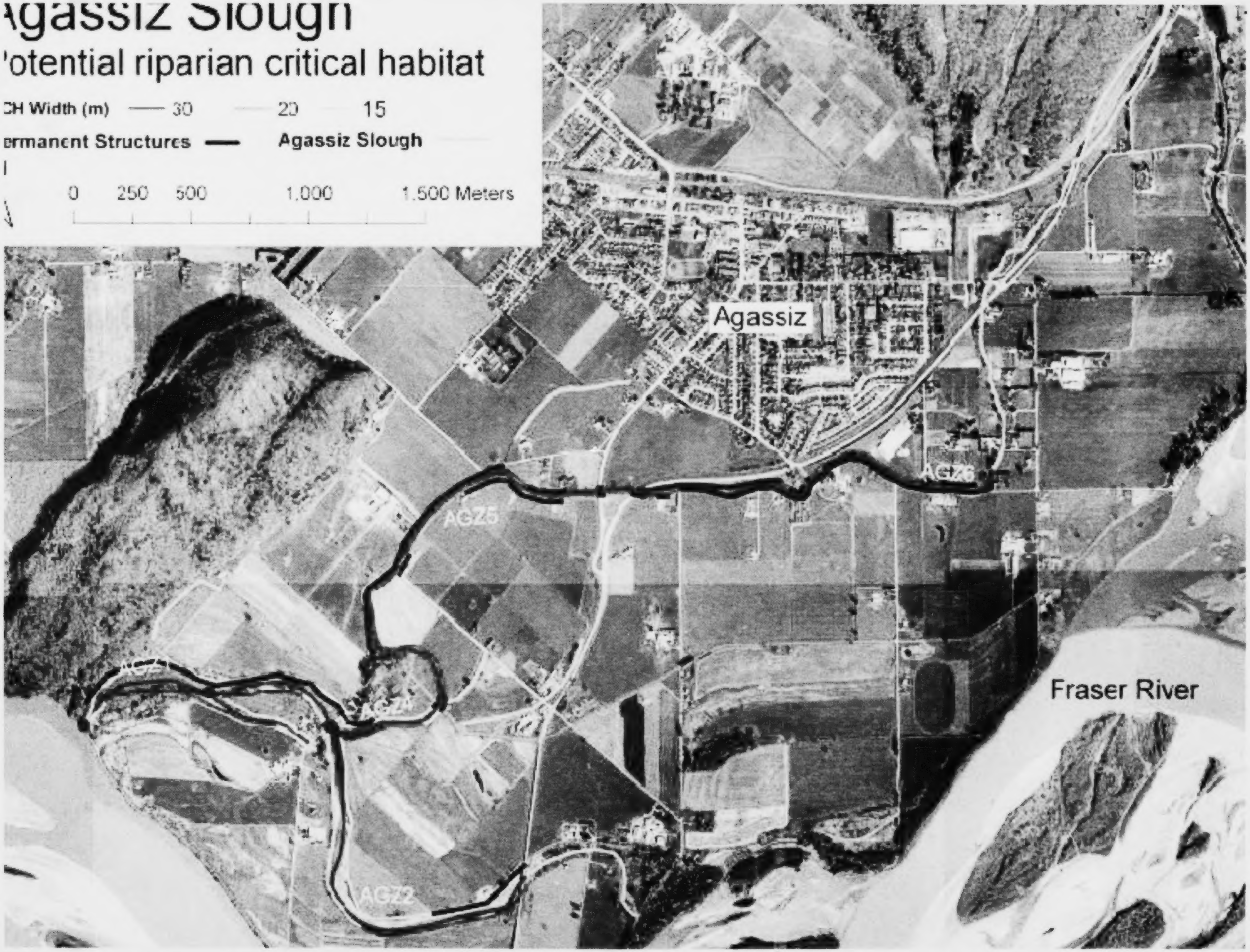
Figure 1: Canadian distributions of Salish sucker and Nooksack dace (Pearson 2004, and Pearson, unpub. data). Maps of all watersheds shown are included except the Little Campbell River, from which Salish suckers are extirpated.



gassiz Slough

otential critical habitat for Salish sucker

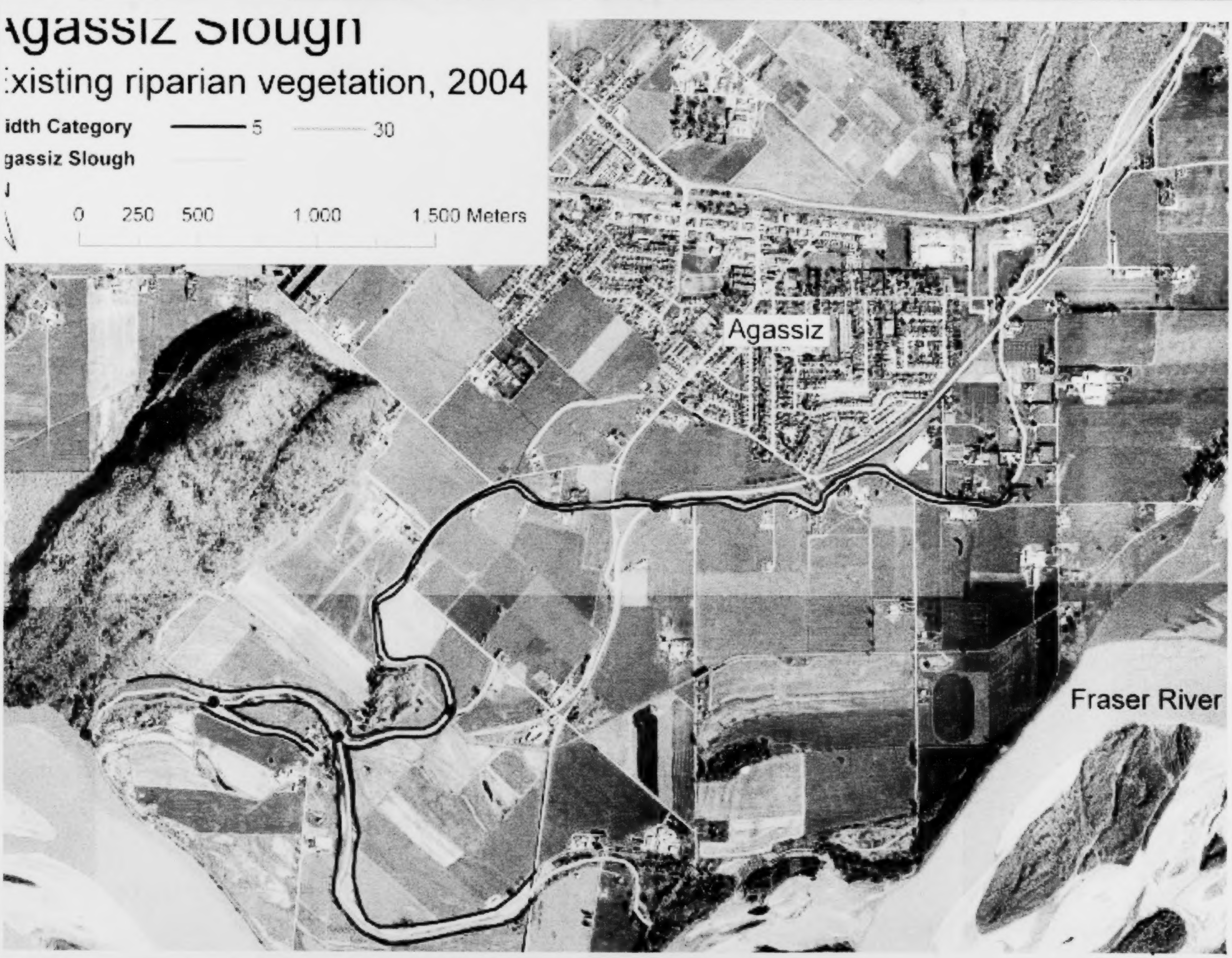
Potential critical habitat
Agassiz Slough
Reach start point
0 250 500 1,000 1,500 Meters
Agassiz
AGZ6
AGZ5
AGZ4
AGZ3
AGZ2
Fraser River

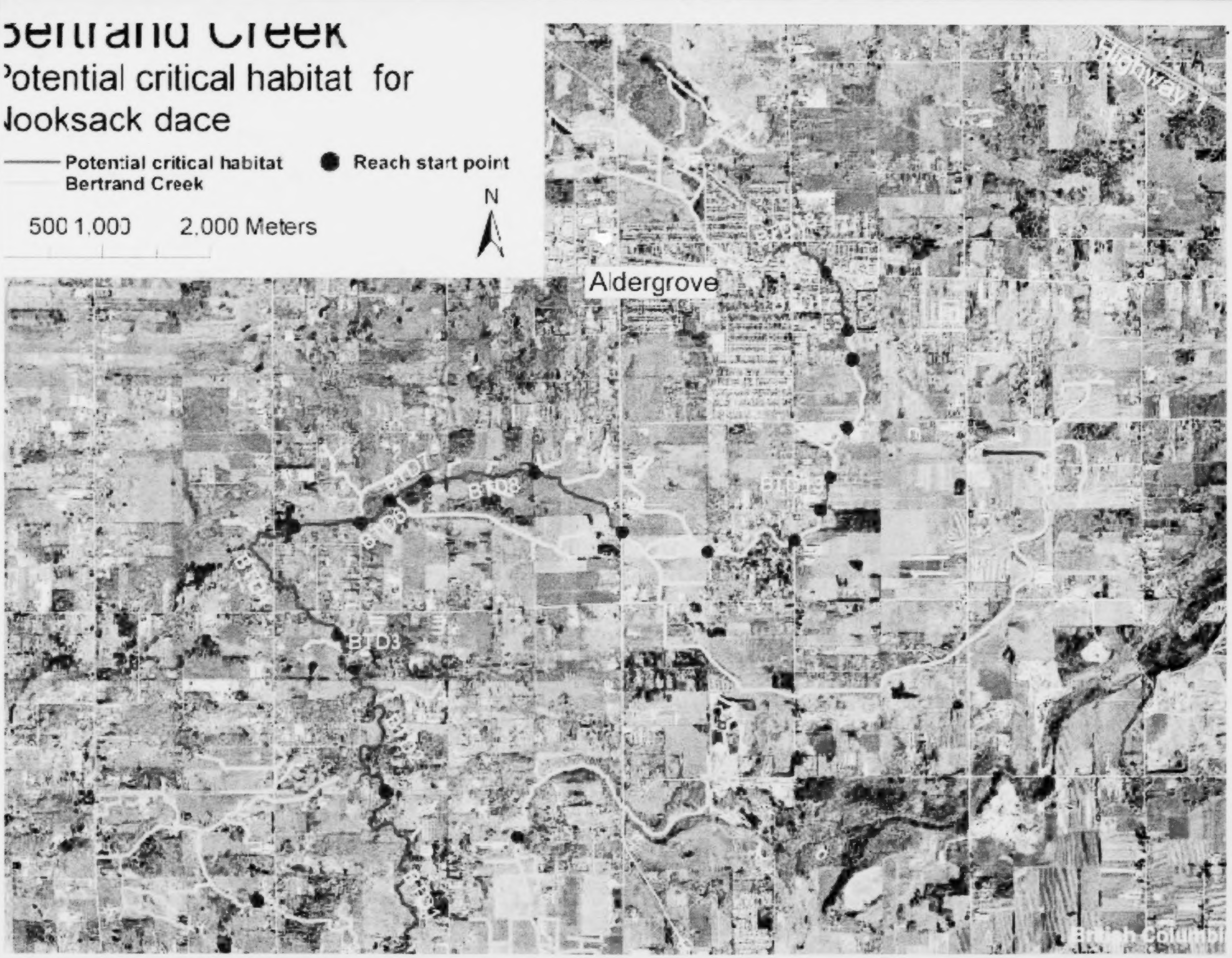


gassiz Slough

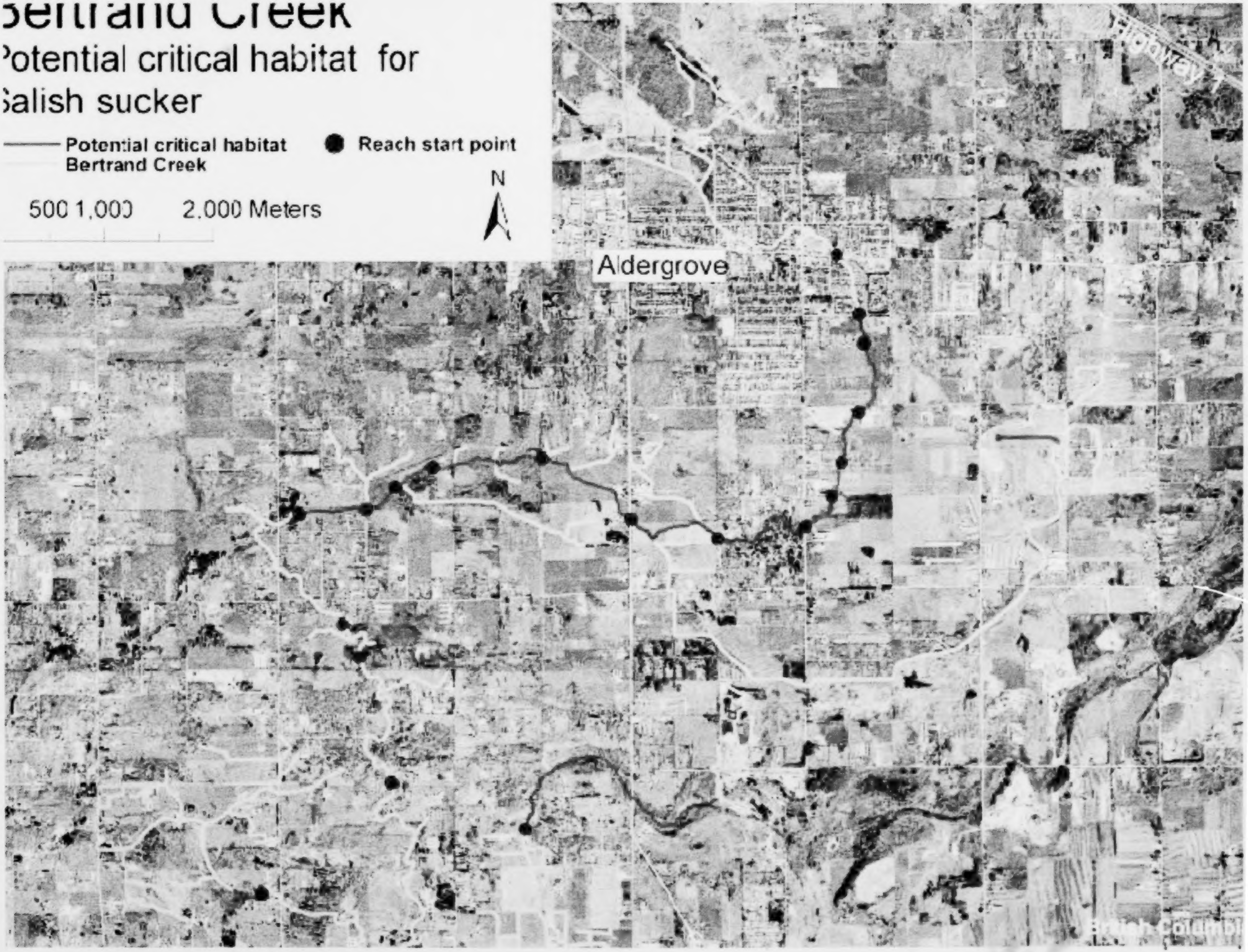
otential riparian critical habitat

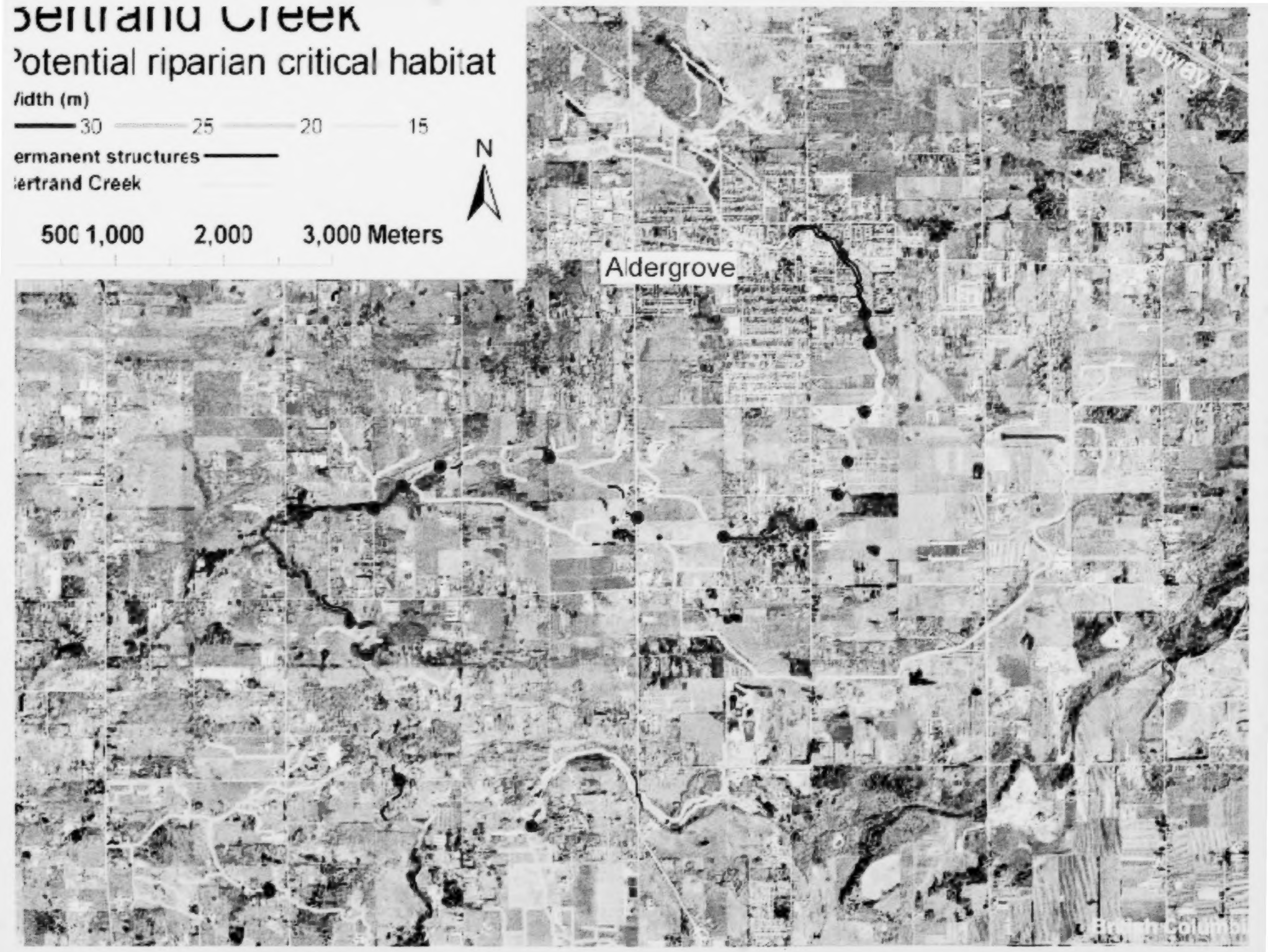
CH Width (m)
30
20
15
ermanent Structures
Agassiz Slough
0
250
500
1,000
1,500 Meters
Agassiz
AGZ5
AGZ6
AGZ4
AGZ2
Fraser River

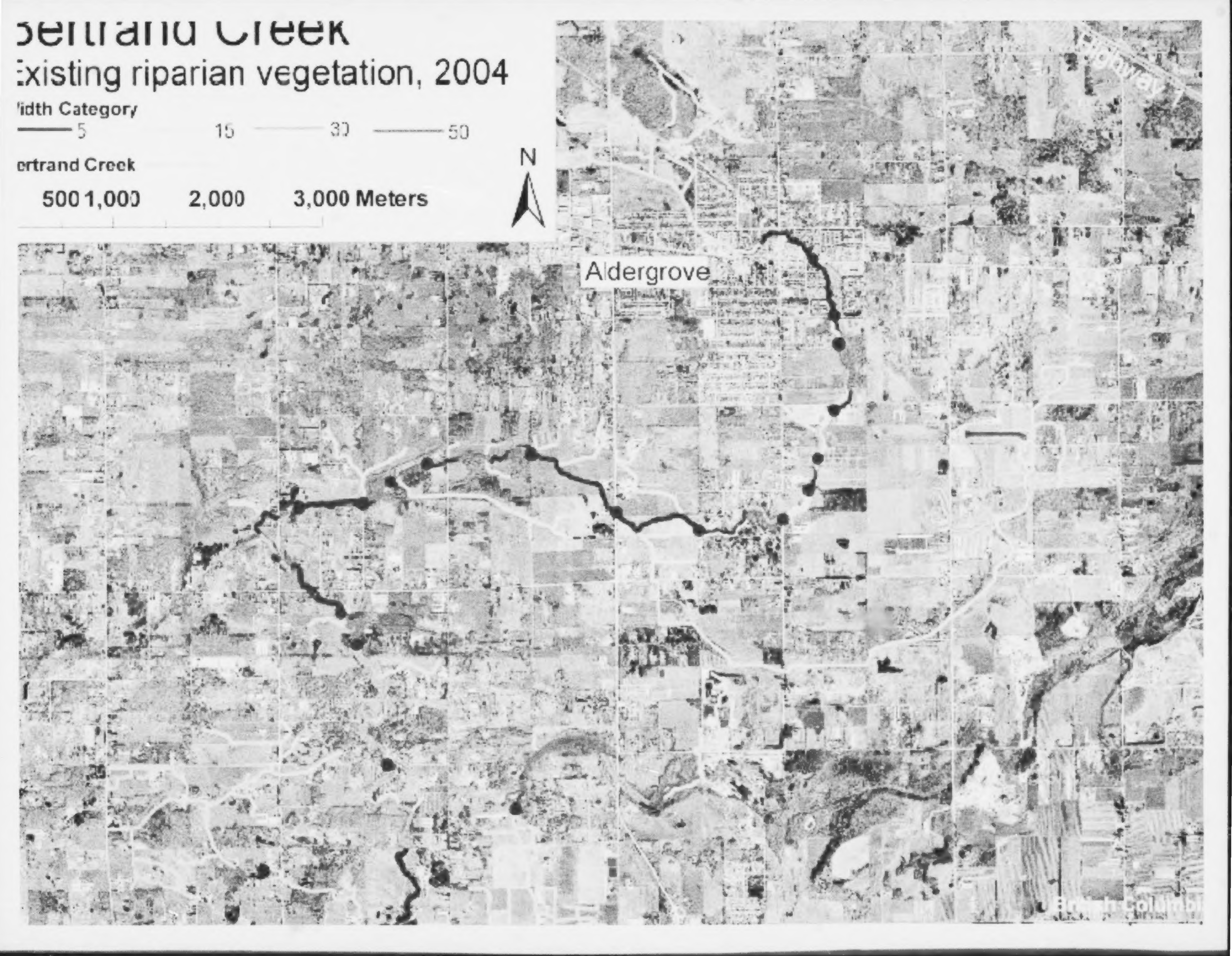

gassiz Slough
xisting riparian vegetation, 2004
idth Category
5
30
gassiz Slough
0
250
500
1,000
1,500 Meters
Agassiz
Fraser River


Bertrand Creek
Potential critical habitat for
Nooksack dace
Potential critical habitat
Bertrand Creek
Reach start point
500 1,000 2,000 Meters
N
Highway 1
Aldergrove
BTD7
BTD8
BTD6
BTD3
British Columbi

Bertrand Creek
Potential critical habitat for Salish sucker


Potential critical habitat
Bertrand Creek
● Reach start point
500 1,000 2,000 Meters
N
Aldergrove
Highway 1
British Columbi

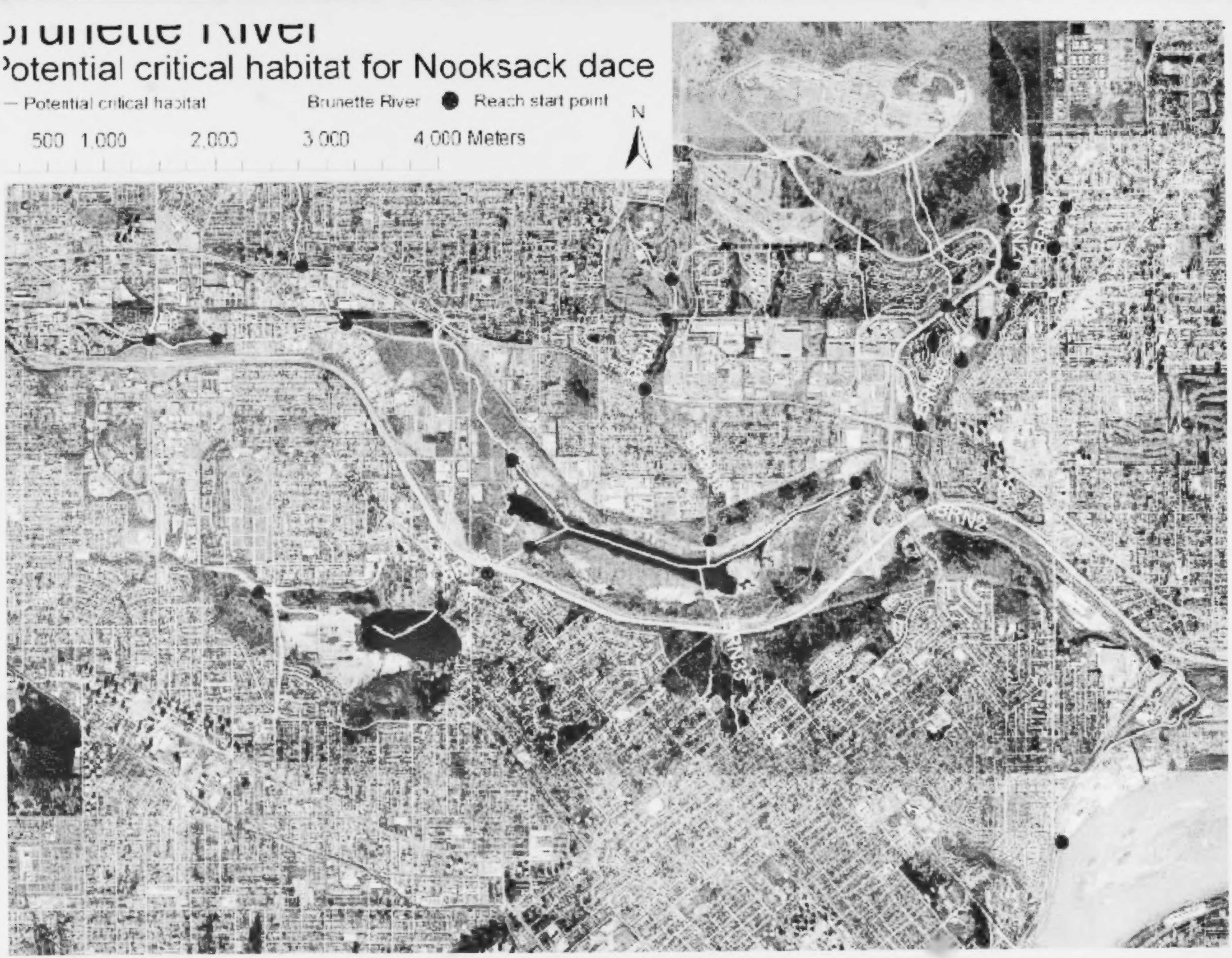

ertrand Creek
otential riparian critical habitat
idth (m)
30
25
20
15
ermanent structures
ertrand Creek
N
500 1,000 2,000 3,000 Meters
Aldergrove
Highway 1
British Columbi

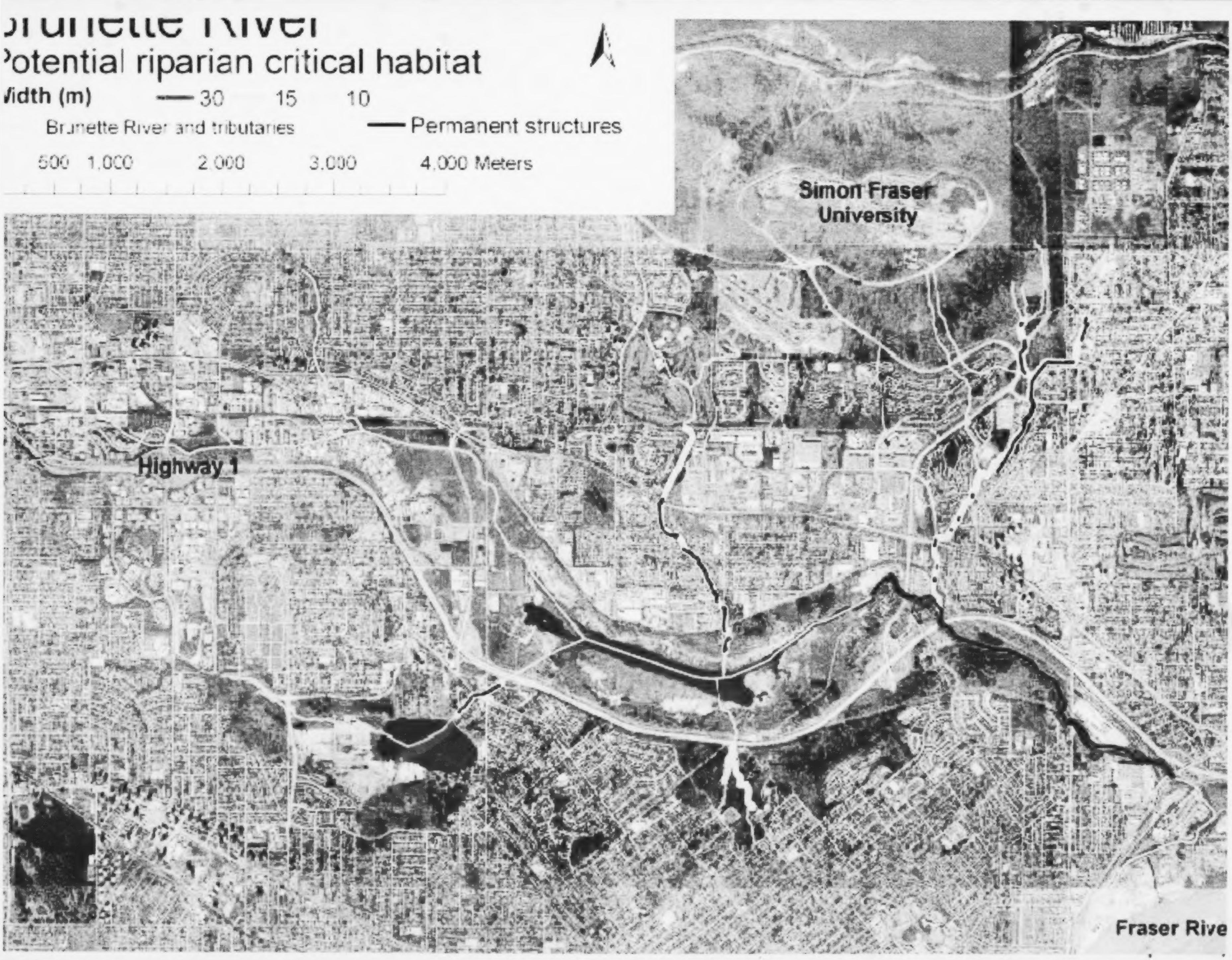


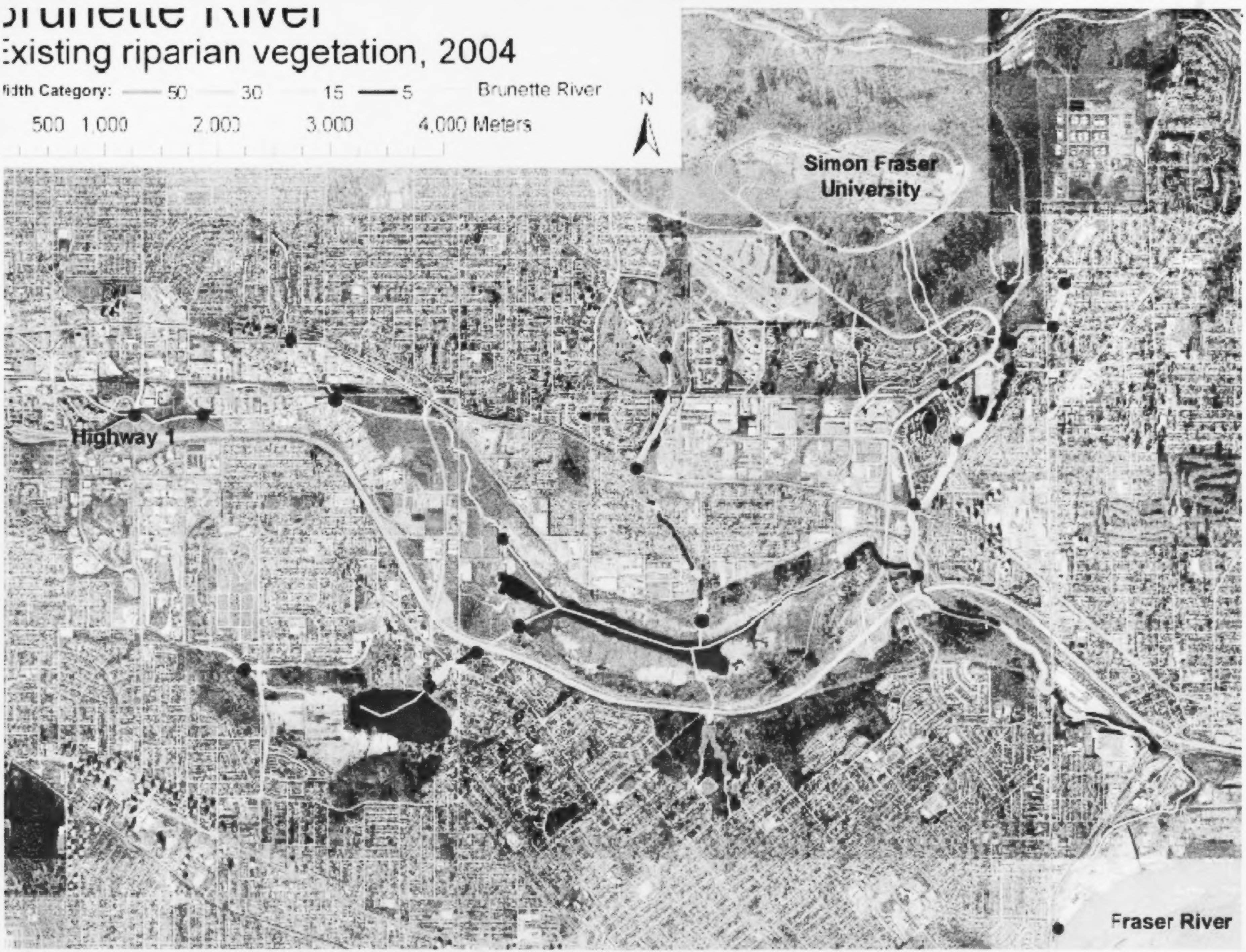
ertrand Creek

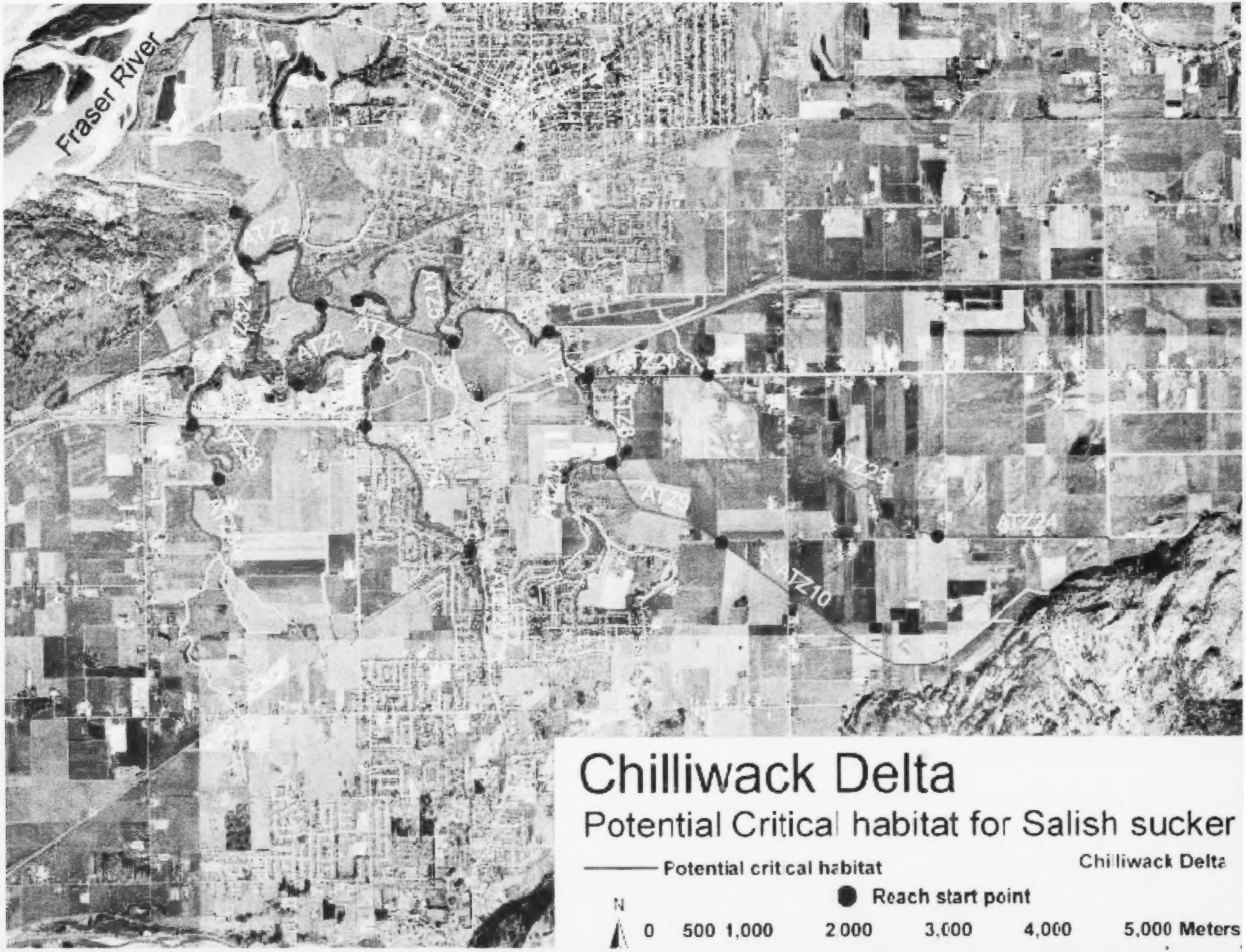
xisting riparian vegetation, 2004

idth Category
5
15
30
50
ertrand Creek
500 1,000
2,000
3,000 Meters
N
Aldergrove
Highway 1
British Columbi


runette River
otential critical habitat for Nooksack dace
Potential critical habitat
Brunette River
● Reach start point
500
1,000
2,000
3,000
4,000 Meters
N


runette River
otential riparian critical habitat
idth (m)
30
15
10
Brunette River and tributaries
Permanent structures
500
1,000
2,000
3,000
4,000 Meters
Simon Fraser University
Highway 1
Fraser Rive

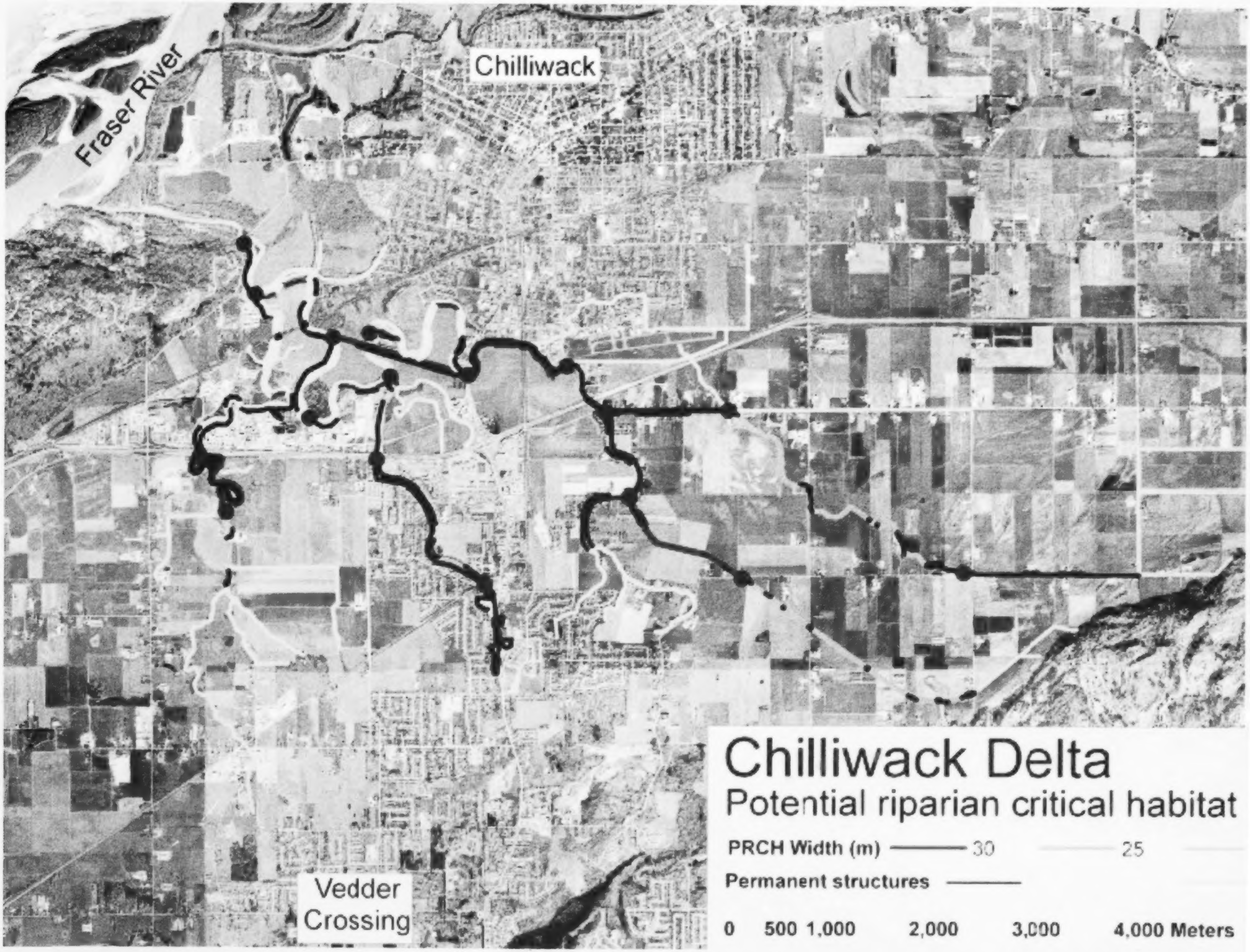
runette River
xisting riparian vegetation, 2004
idth Category: 50 30 15 5 Brunette River
500 1,000 2,000 3,000 4,000 Meters
N
Simon Fraser University
Highway 1
Fraser River

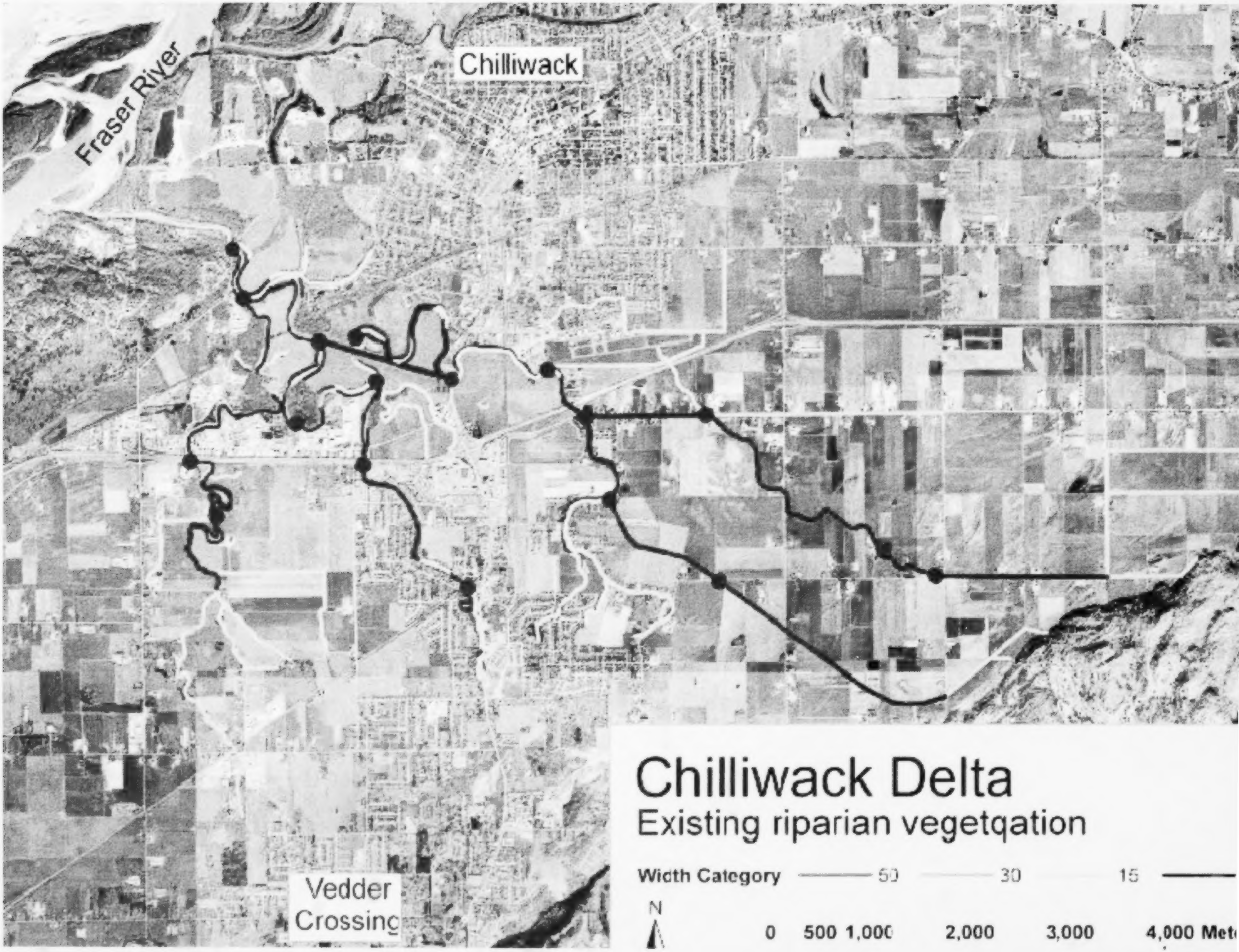


Chilliwack Delta

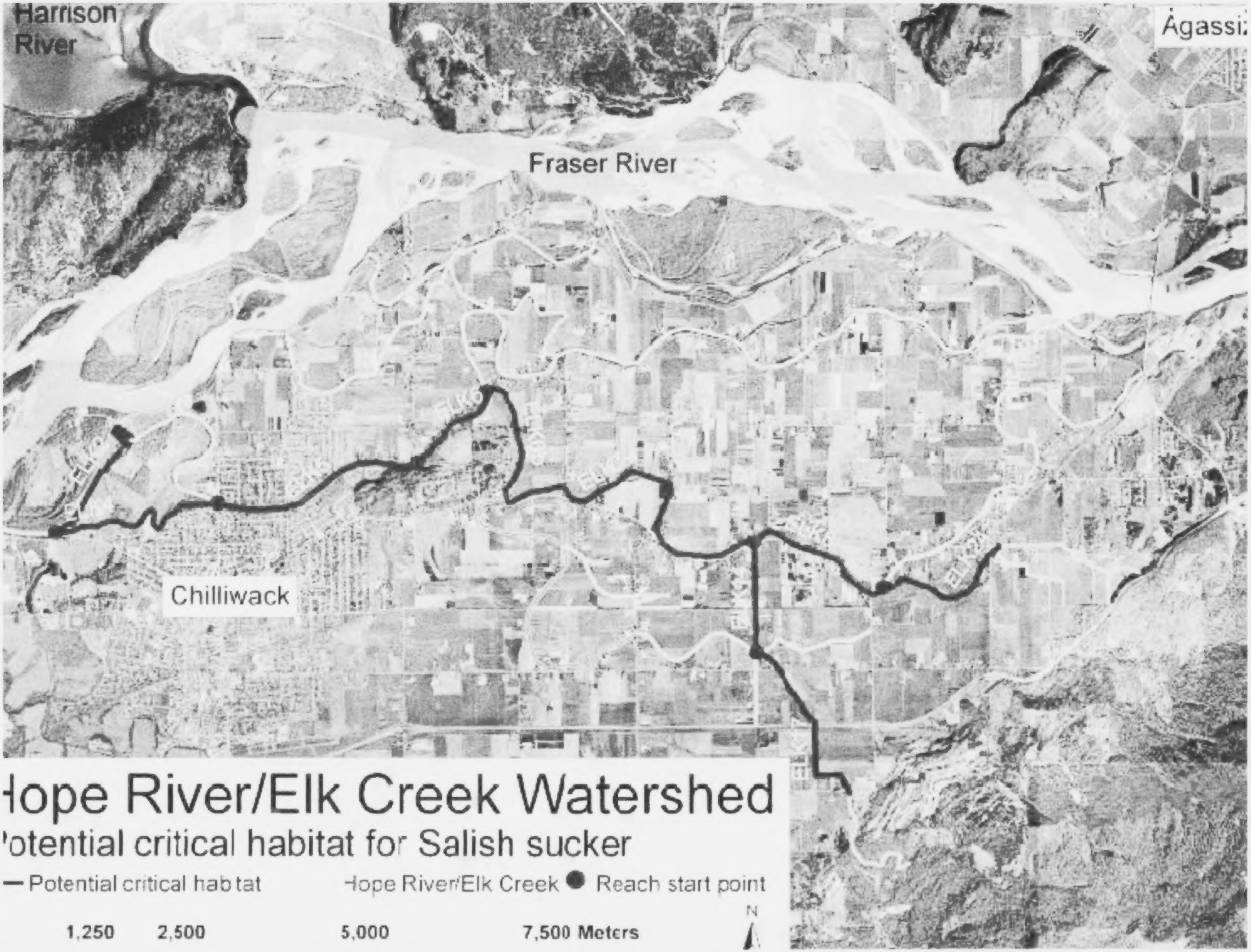
Potential Critical habitat for Salish sucker

Fraser River
ATZ2
ATZ3
ATZ4
ATZ5
ATZ6
ATZ7
ATZ8
ATZ9
ATZ10
ATZ20
ATZ23
ATZ24
Potential critical habitat
Chilliwack Delta
Reach start point
N
0
500
1,000
2000
3,000
4,000
5,000 Meters


Fraser River
Chilliwack
Vedder Crossing
Chilliwack Delta
Potential riparian critical habitat
PRCH Width (m) 30 25
Permanent structures
0 500 1,000 2,000 3,000 4,000 Meters

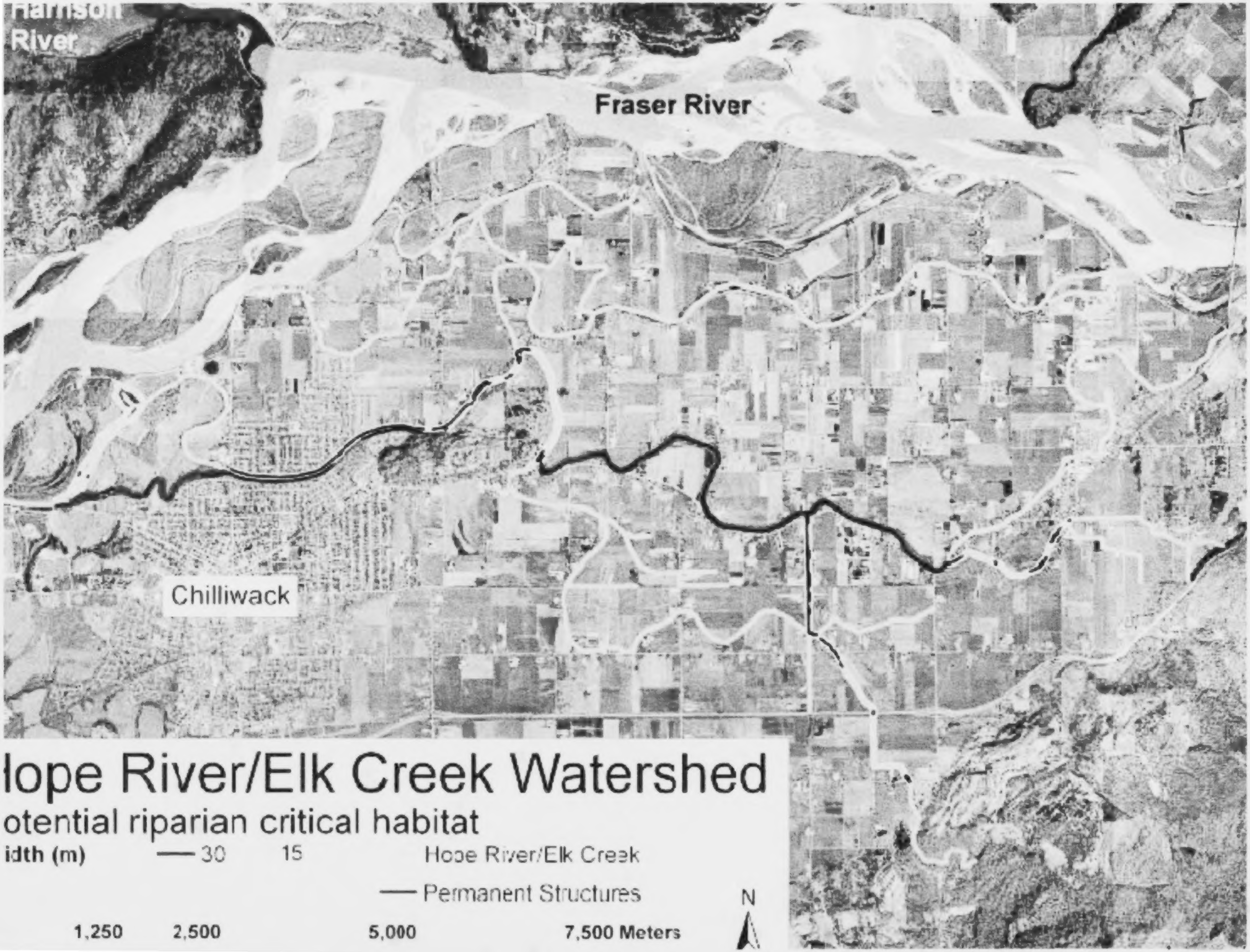

Fraser River
Chilliwack
Vedder Crossing
Width Category
50
30
15
N
0
500
1,000
2,000
3,000
4,000 Met

Chilliwack Delta
Existing riparian vegetqation


Harrison River
Agassi:
Fraser River
Chilliwack
Elk Creek
— Potential critical hab tat
Hope River/Elk Creek
● Reach start point
1,250
2,500
5,000
7,500 Meters
N

Hope River/Elk Creek Watershed

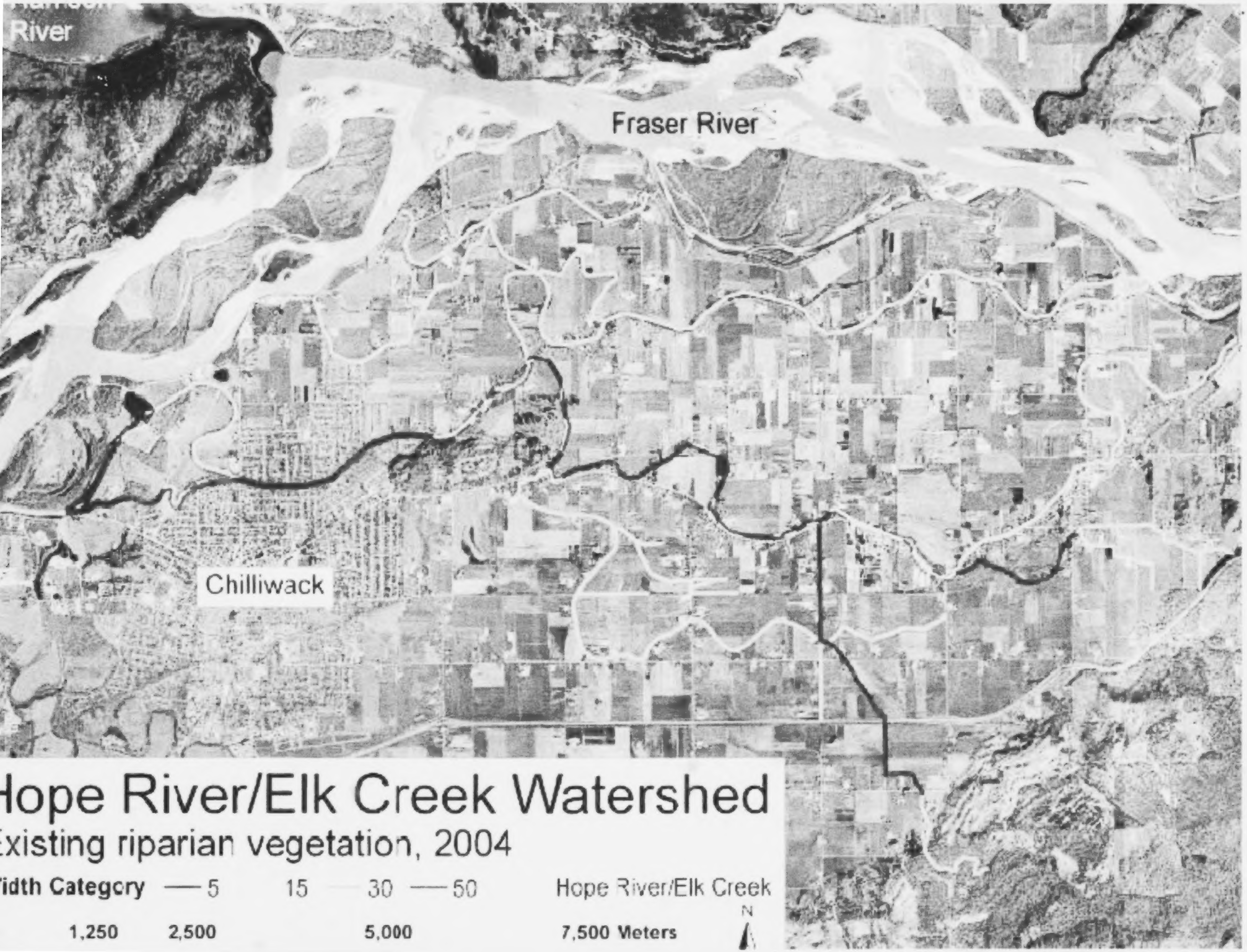
Potential critical habitat for Salish sucker



lope River/Elk Creek Watershed

otential riparian critical habitat

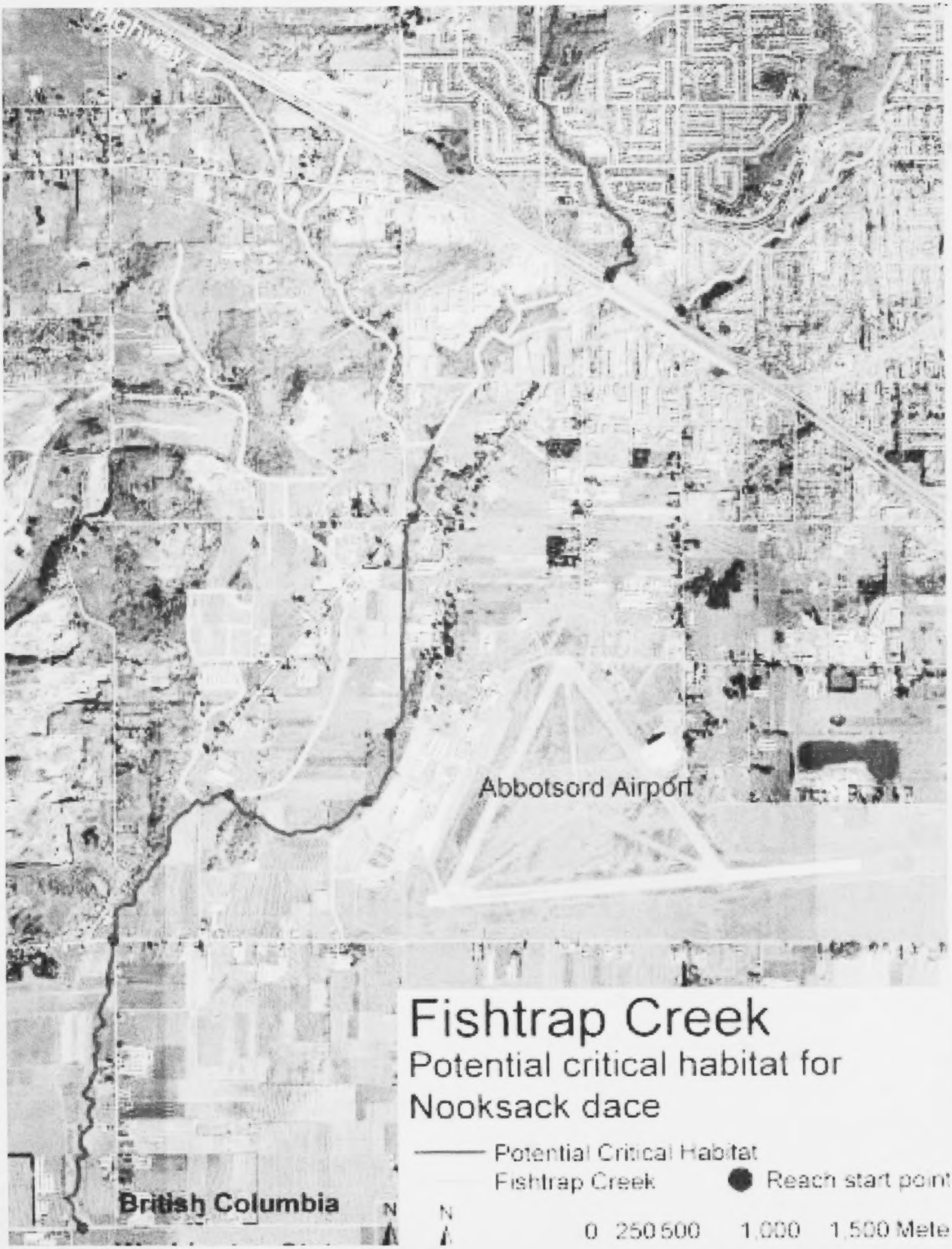
Harrison
River
Fraser River
Chilliwack
idth (m)
30
15
Hope River/Elk Creek
Permanent Structures
1,250
2,500
5,000
7,500 Meters
N



lope River/Elk Creek Watershed

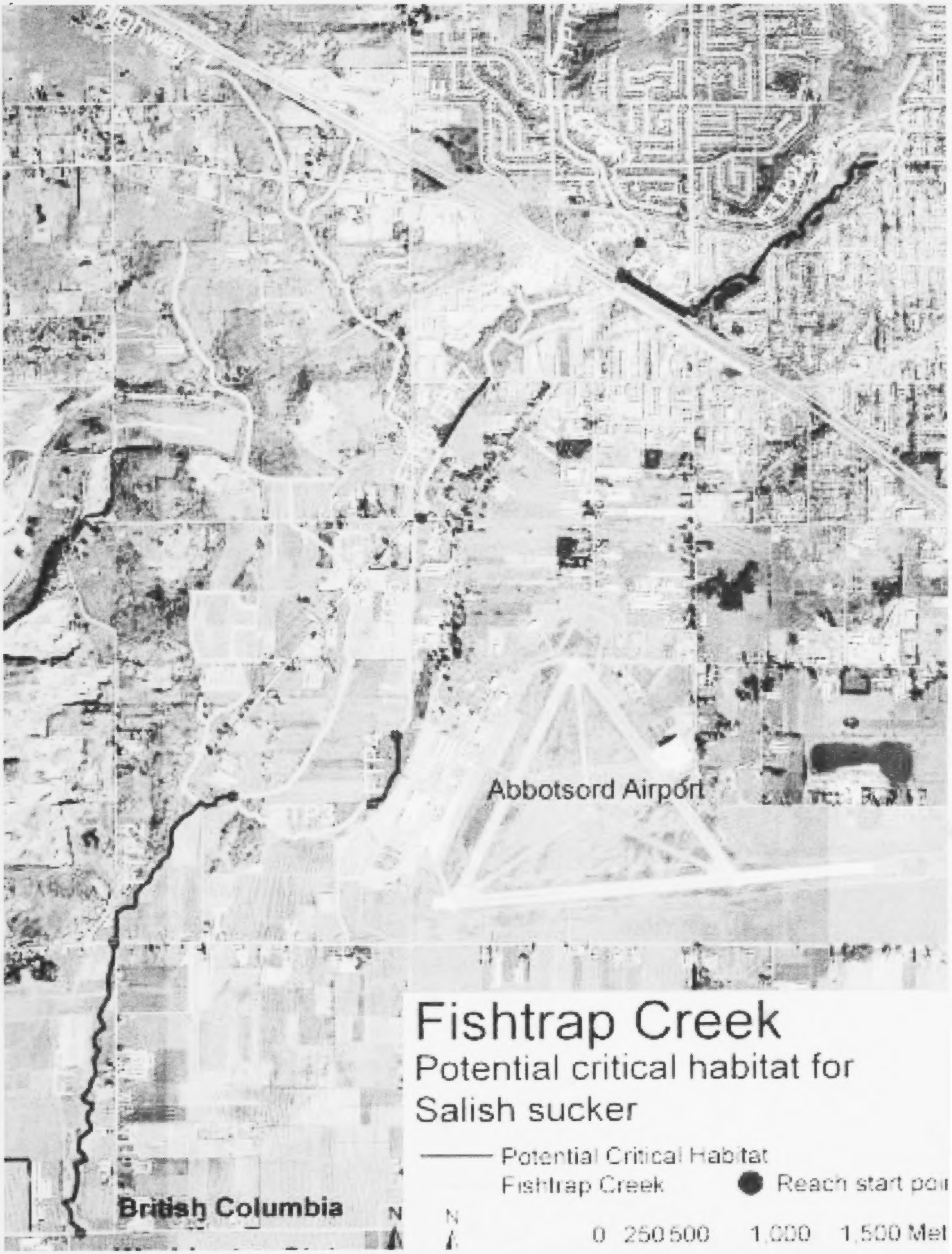
xisting riparian vegetation, 2004

River
Fraser River
Chilliwack
idth Category — 5 15 30 — 50
Hope River/Elk Creek
1,250 2,500 5,000 7,500 Meters
N


Fishtrap Creek

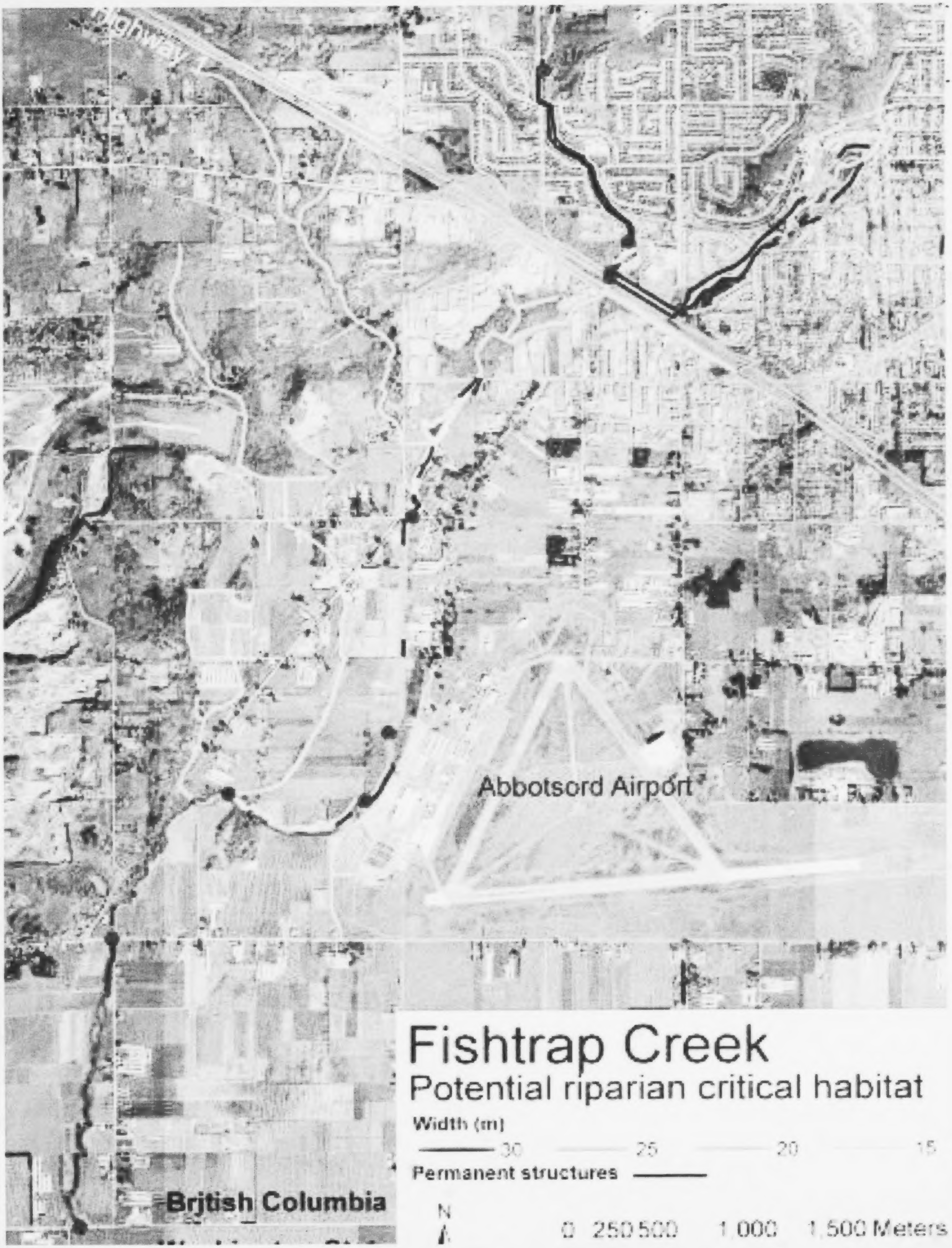
Potential critical habitat for Nooksack dace

ghway
Abbotsord Airport
British Columbia
Potential Critical Habitat
Fishtrap Creek
Reach start poin
N
0 250 500 1,000 1,500 Mete



Fishtrap Creek
Potential critical habitat for Salish sucker

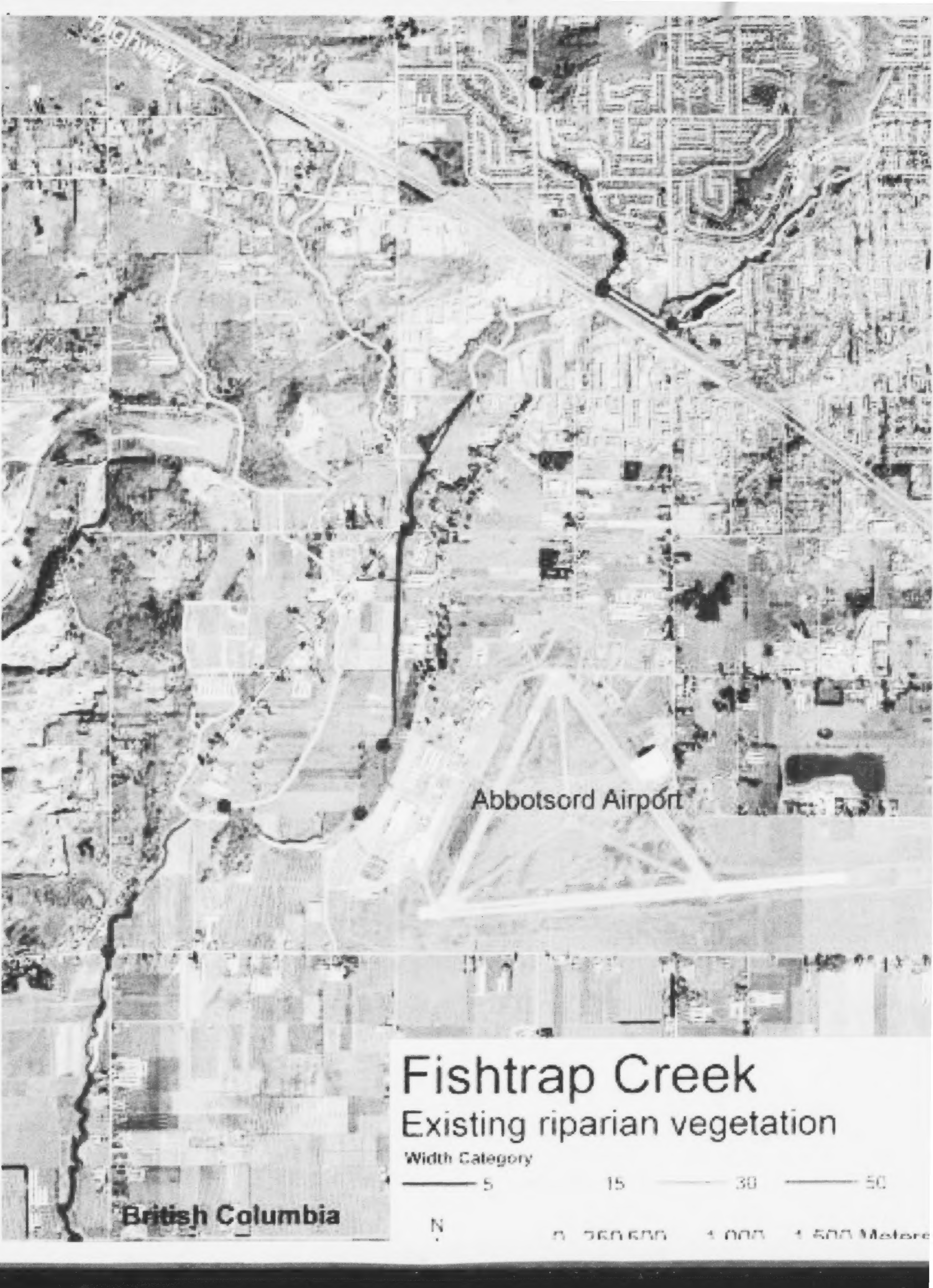
Abbotsord Airport
British Columbia
Potential Critical Habitat
Fishtrap Creek
Reach start poi
N
0 250 500 1,000 1,500 Met



Fishtrap Creek

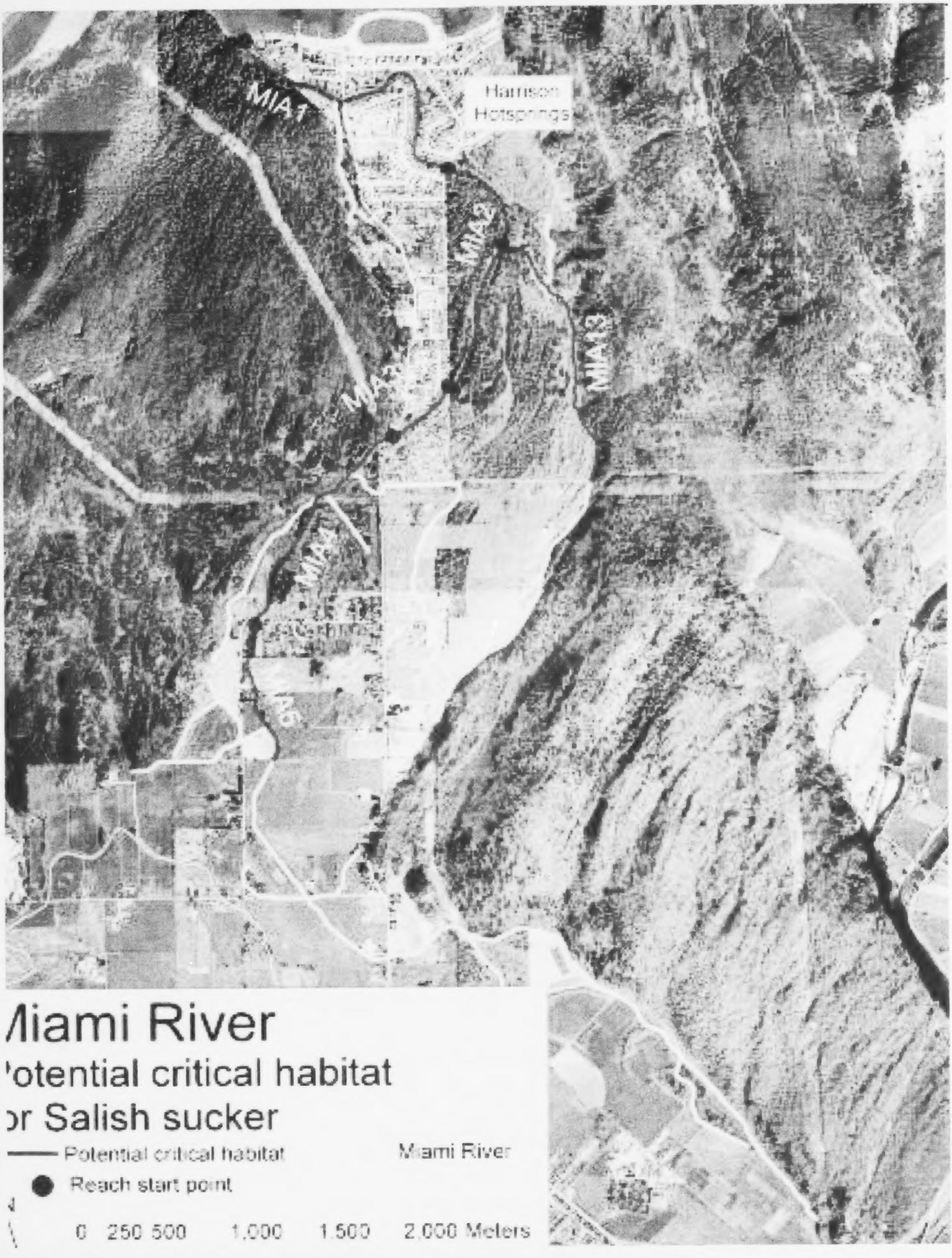
Potential riparian critical habitat

Highway
Abbotsord Airport
British Columbia
Width (m)
30
25
20
15
Permanent structures
N
0 250 500 1,000 1,500 Meters

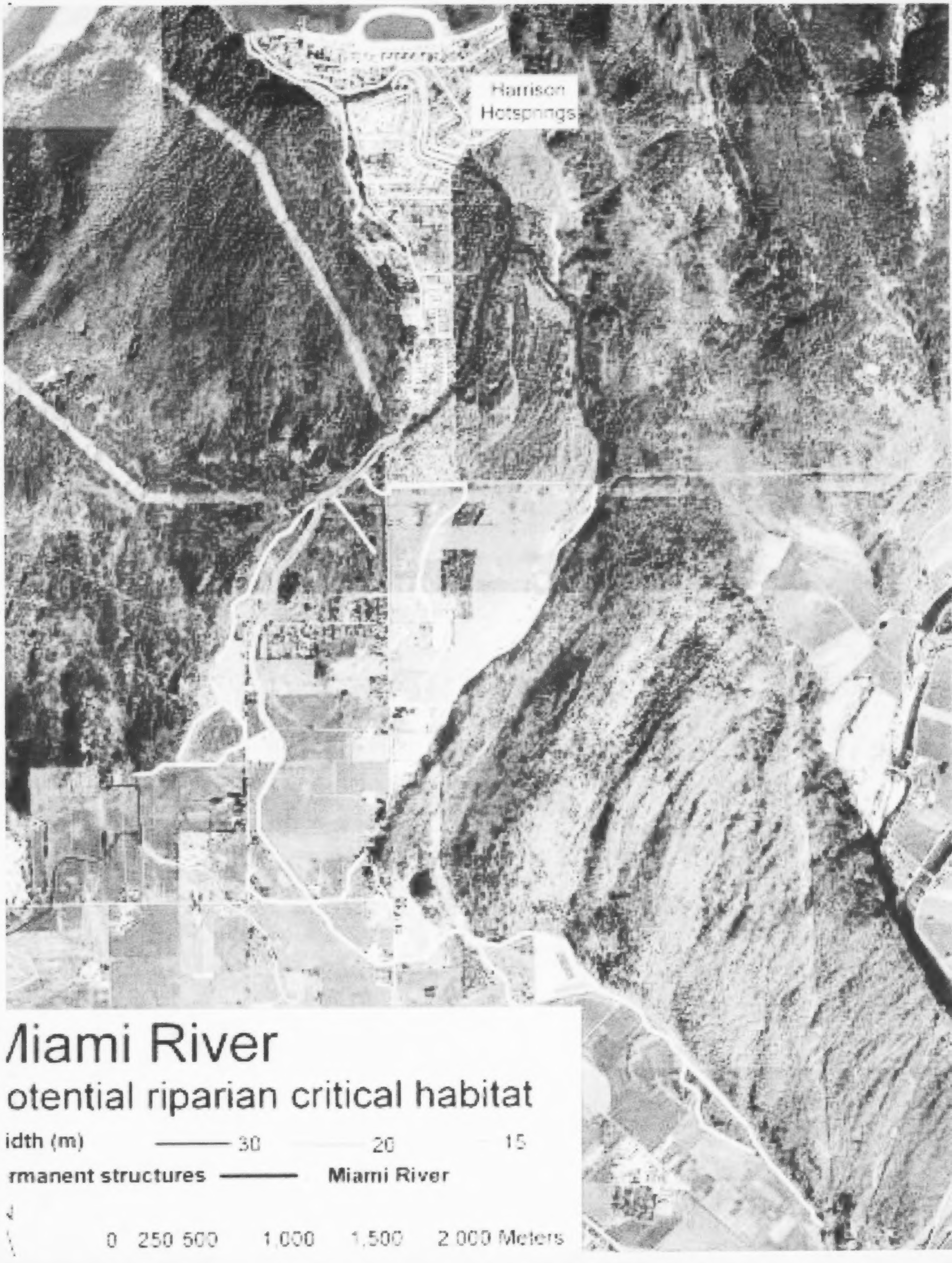

Highway 1
Abbotsord Airport
British Columbia
Width Category
5
15
30
50
N
0 250 500 1,000 1,500 Meters

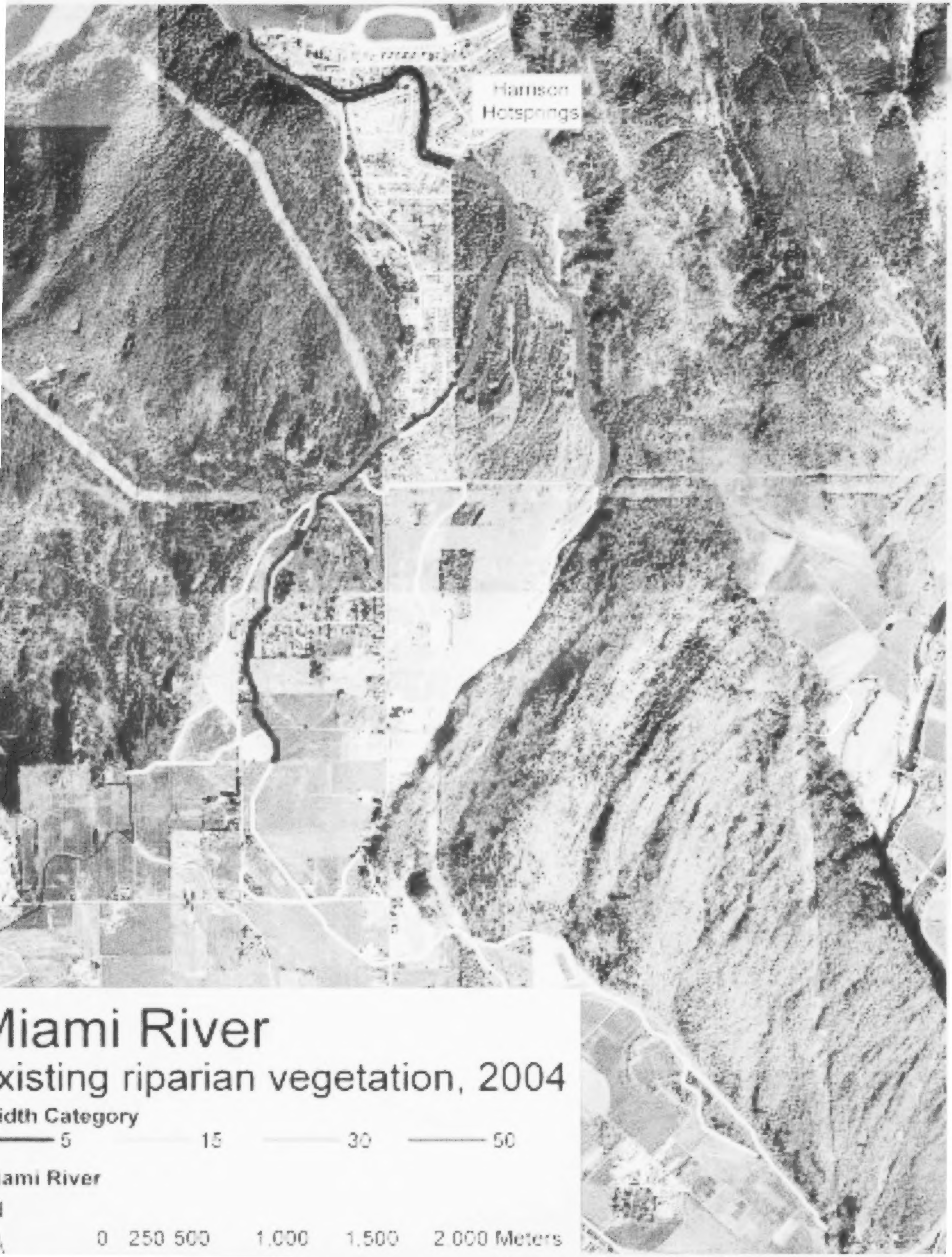
Fishtrap Creek

Existing riparian vegetation


MIA1
Harrison Hotsprings
MIA2
MIA13
MIA3
MIA4
MIA5
Potential critical habitat
Miami River
Reach start point
0 250 500 1,000 1,500 2,000 Meters

iami River
otential critical habitat
r Salish sucker

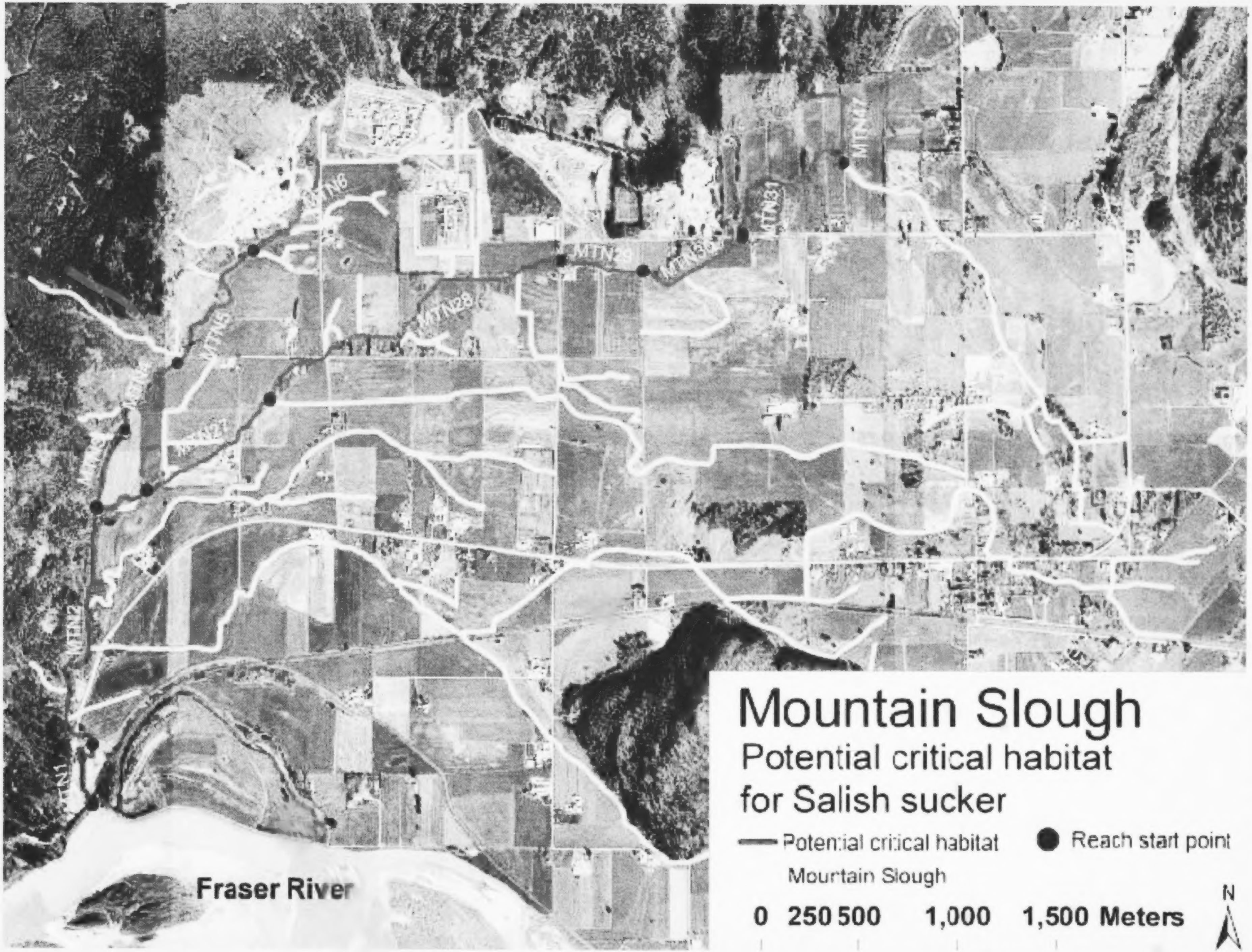

Harrison Hotsprings
iami River
otential riparian critical habitat
idth (m)
30
20
15
rmanent structures
Miami River
0 250 500 1,000 1,500 2,000 Meters

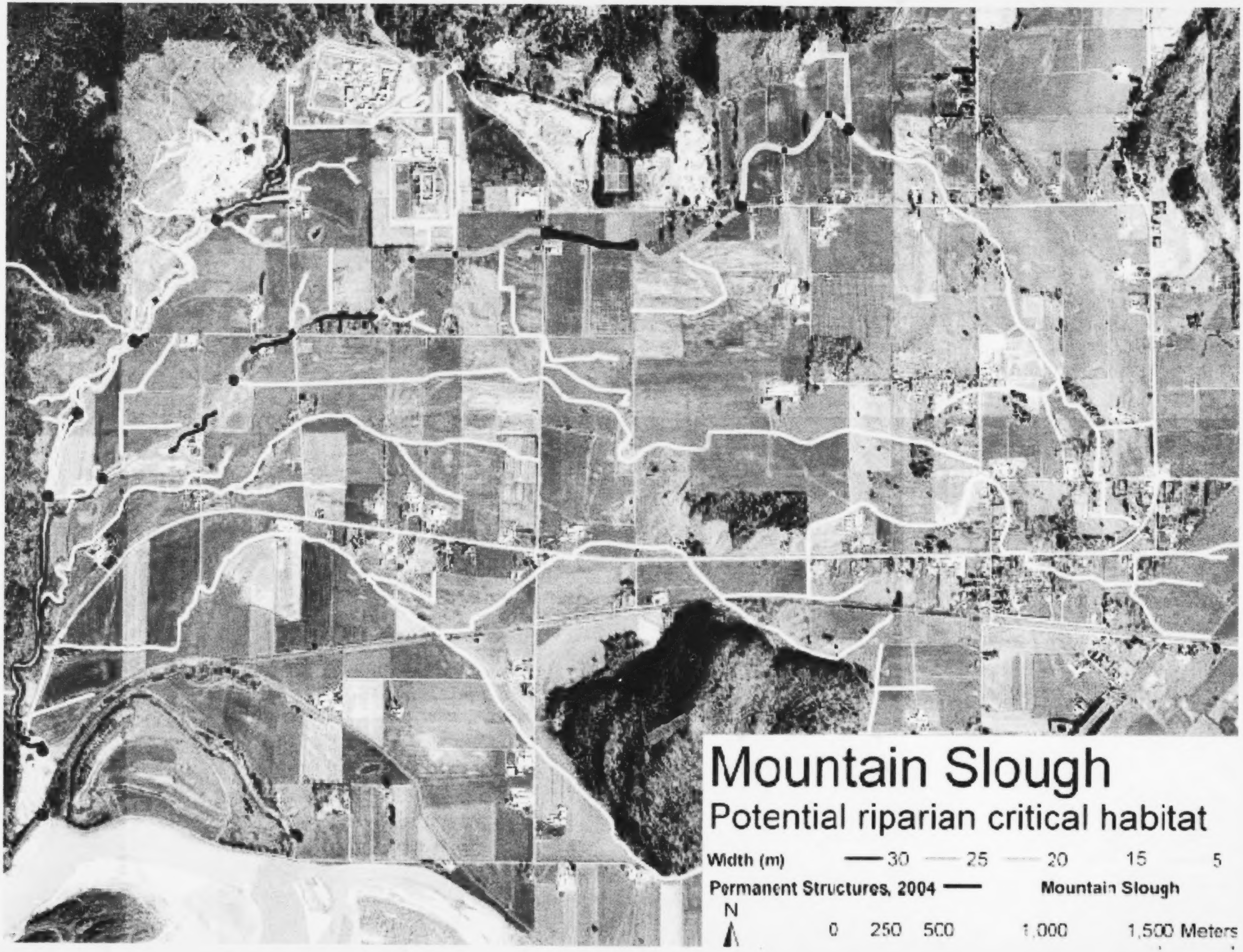


Miami River

xisting riparian vegetation, 2004

Harrison
Hotsprings
idth Category
5
15
30
50
iami River
0 250 500 1,000 1,500 2,000 Meters

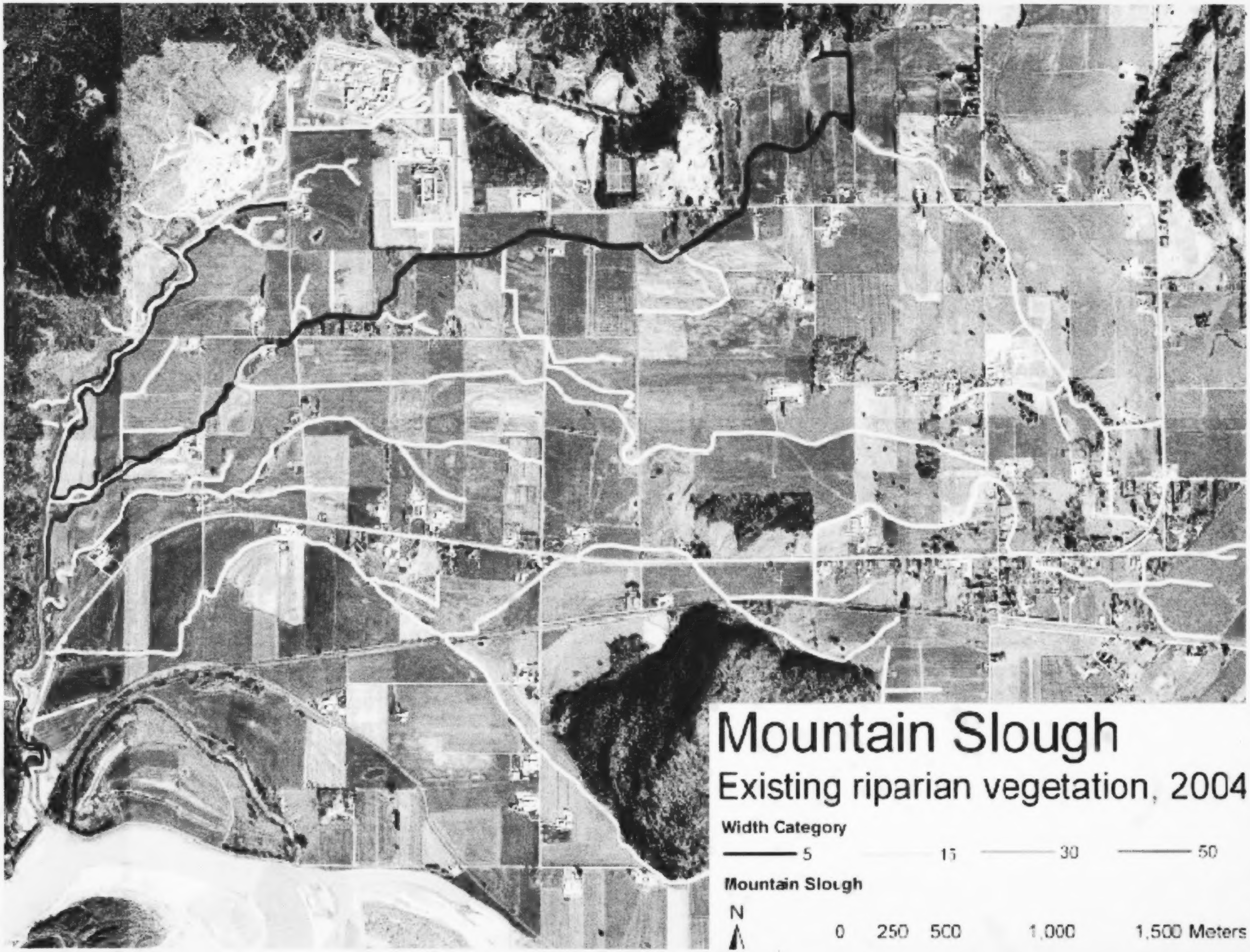

Mountain Slough
Potential critical habitat
for Salish sucker
Potential critical habitat
Reach start point
Mountain Slough
0 250 500 1,000 1,500 Meters
N
Fraser River
MTN8
MTN29
MTN31
MTN28
MTN5
MTN21
MTN2
MTN1



Mountain Slough

Potential riparian critical habitat

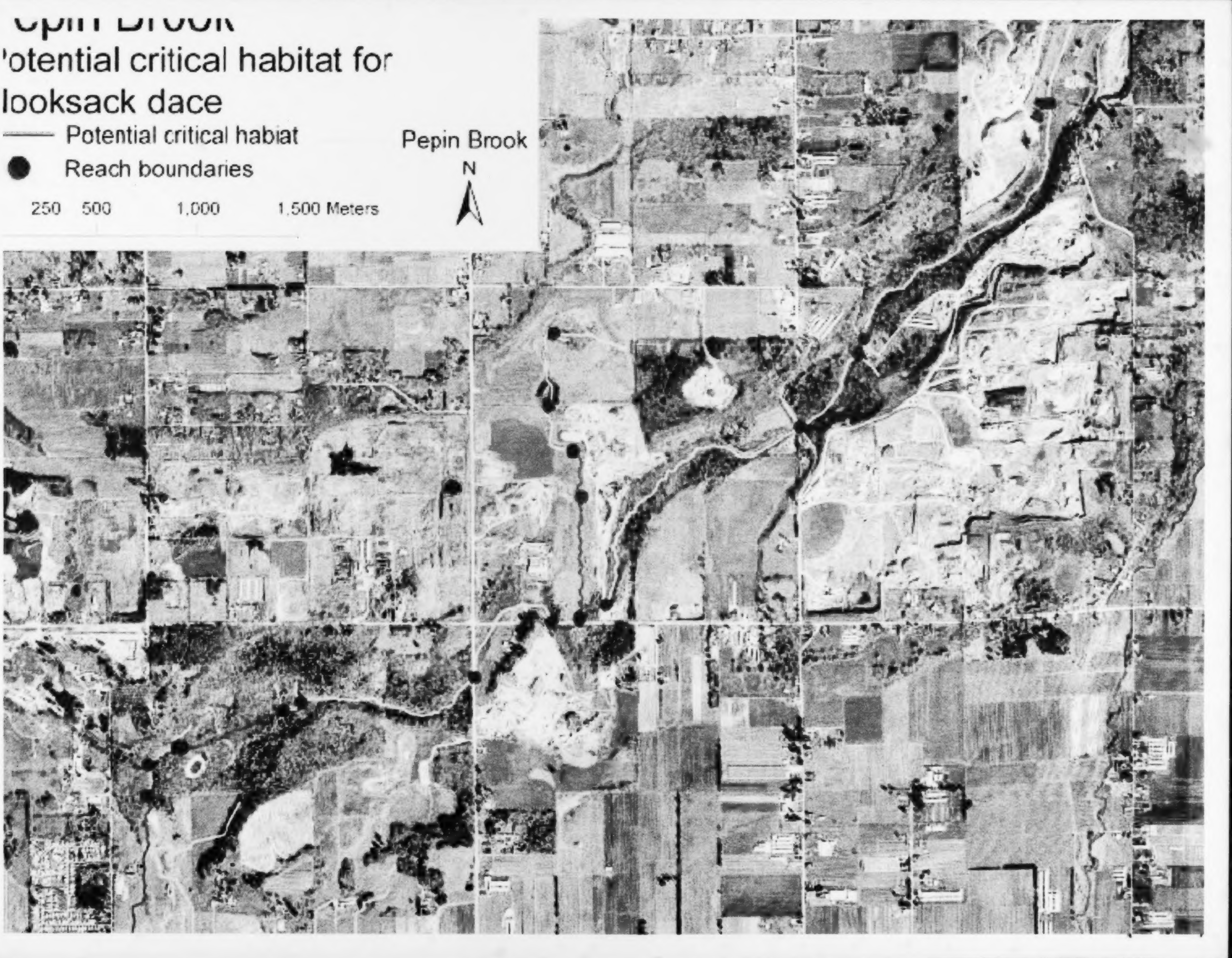
Width (m)
30
25
20
15
5
Permanent Structures, 2004
Mountain Slough
N
0
250
500
1,000
1,500 Meters



Mountain Slough

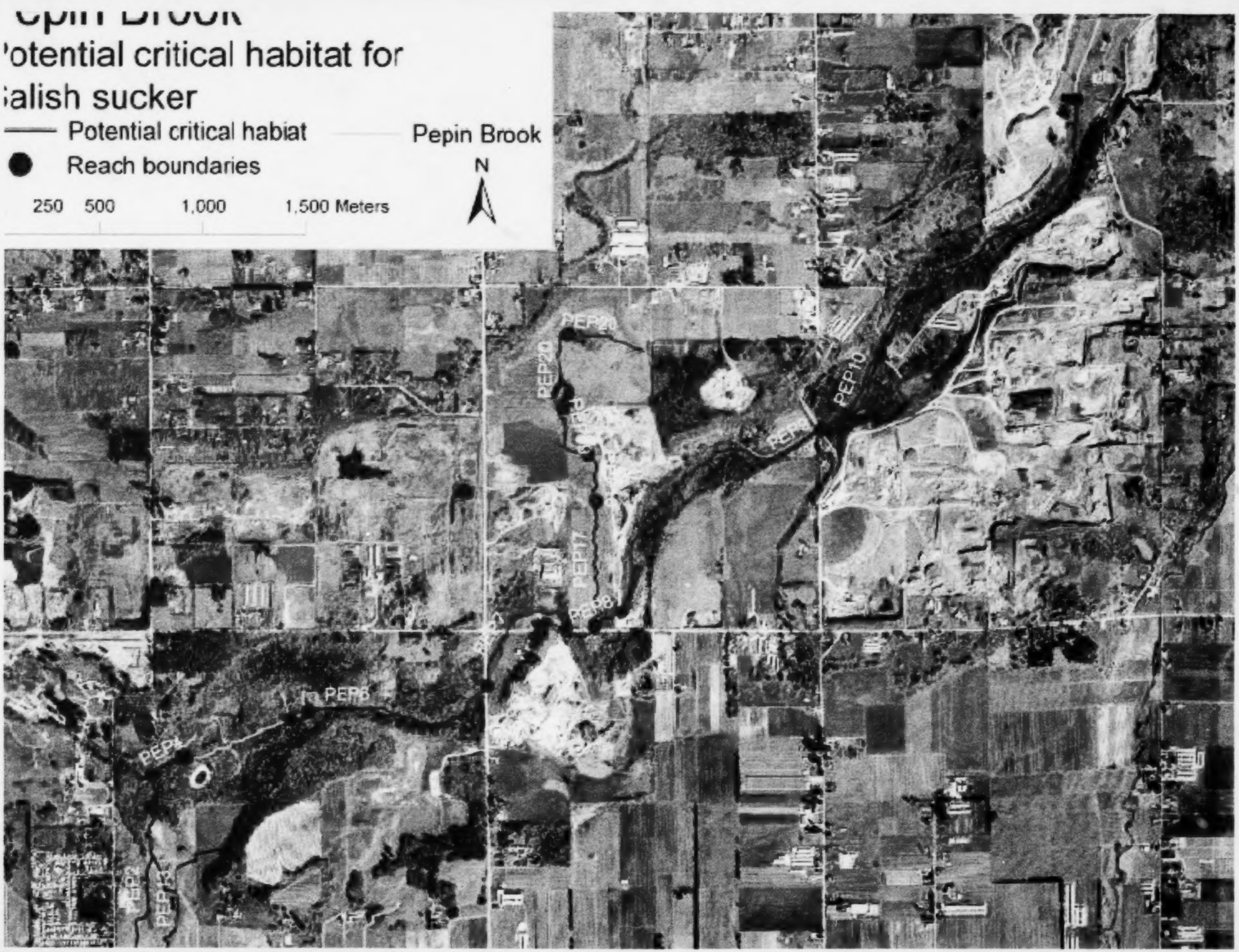
Existing riparian vegetation, 2004

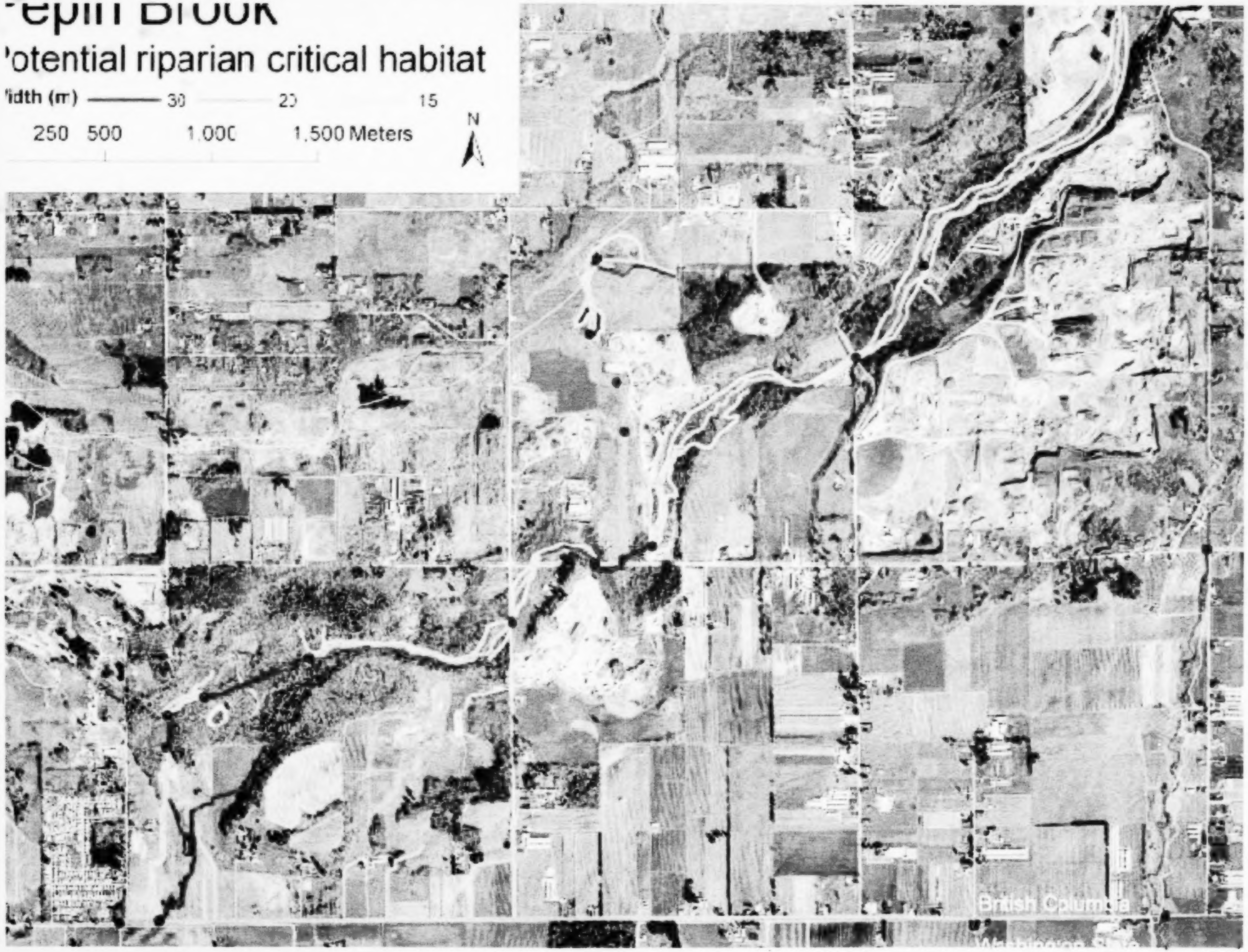
Width Category
5
15
30
50
Mountain Slough
N
0
250
500
1,000
1,500 Meters



epin Brook
'otential critical habitat for
looksack dace

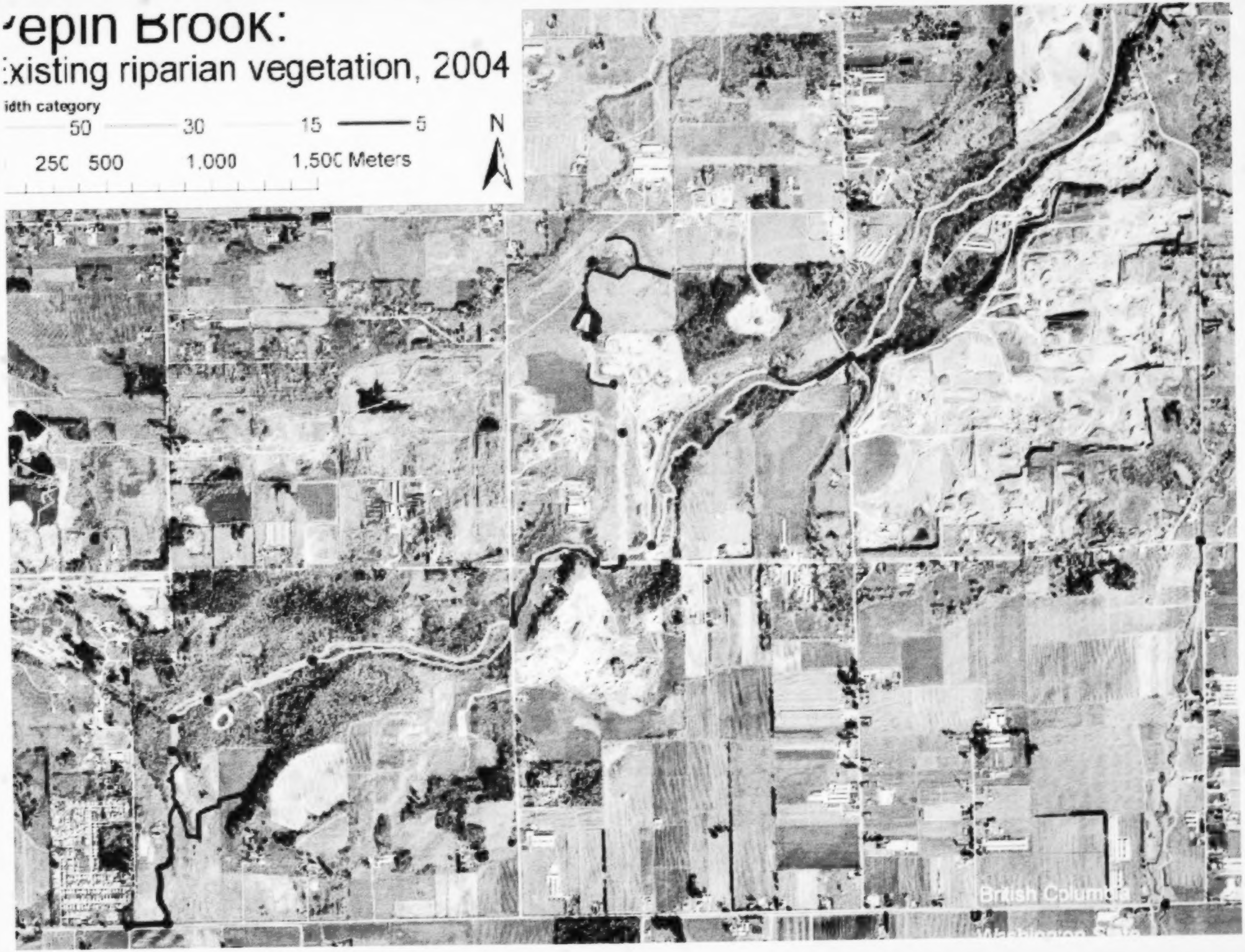
Potential critical habiat
● Reach boundaries
250
500
1,000
1,500 Meters
Pepin Brook
N

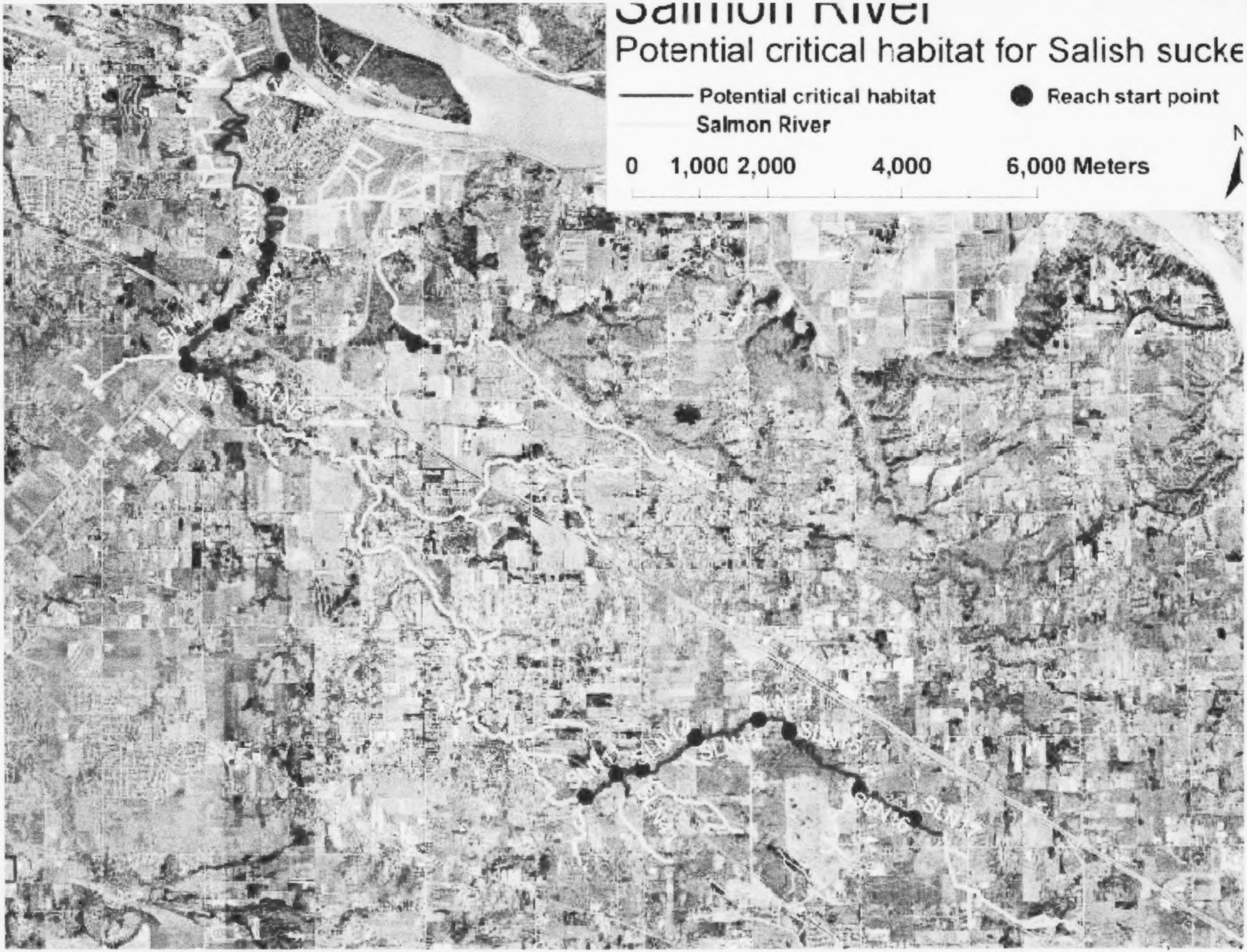

epin Brook
otential critical habitat for
alish sucker
Potential critical habiat
Pepin Brook
Reach boundaries
N
250 500 1,000 1,500 Meters
PEP20
PEP20
PEP10
PEP9
PEP17
PEP8
PEP5
PEP4
PEP3
PEP2


epin Brook
otential riparian critical habitat
idth (m) 30 20 15
250 500 1,000 1,500 Meters
N
British Columbia
Washington State

epin Brook:

xisting riparian vegetation, 2004

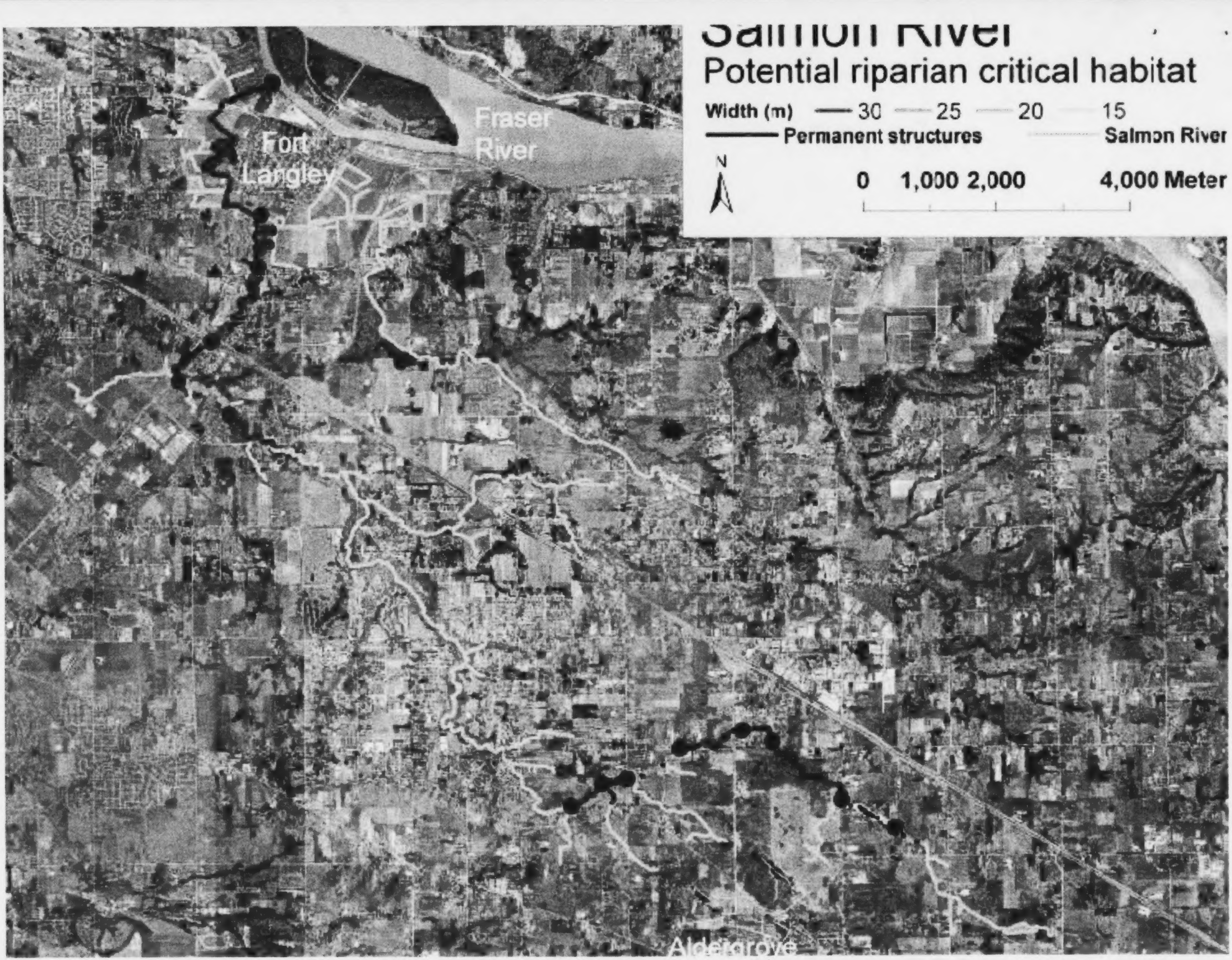

idth category
50
30
15
5
250 500 1,000 1,500 Meters
N
British Columbia
Washington State

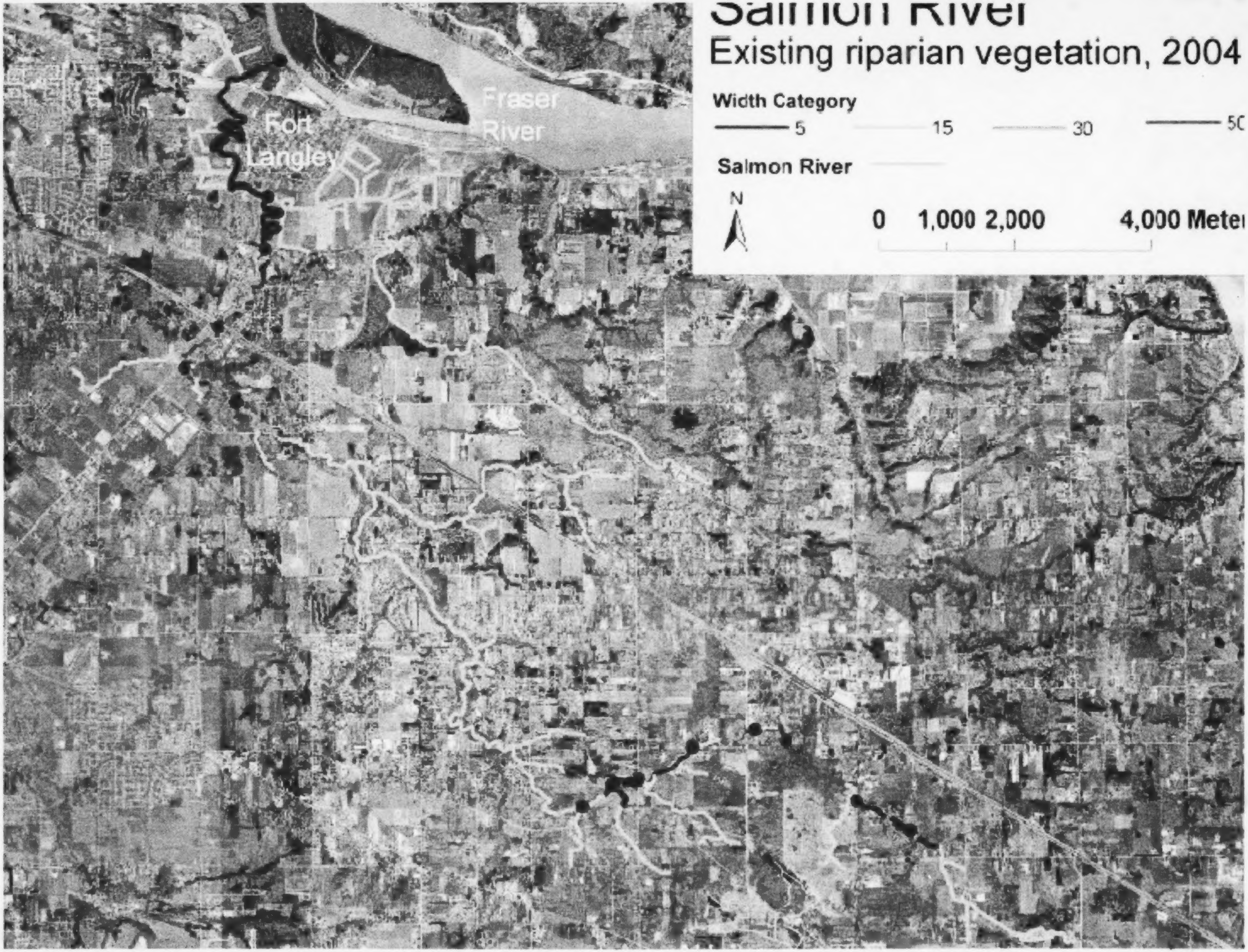


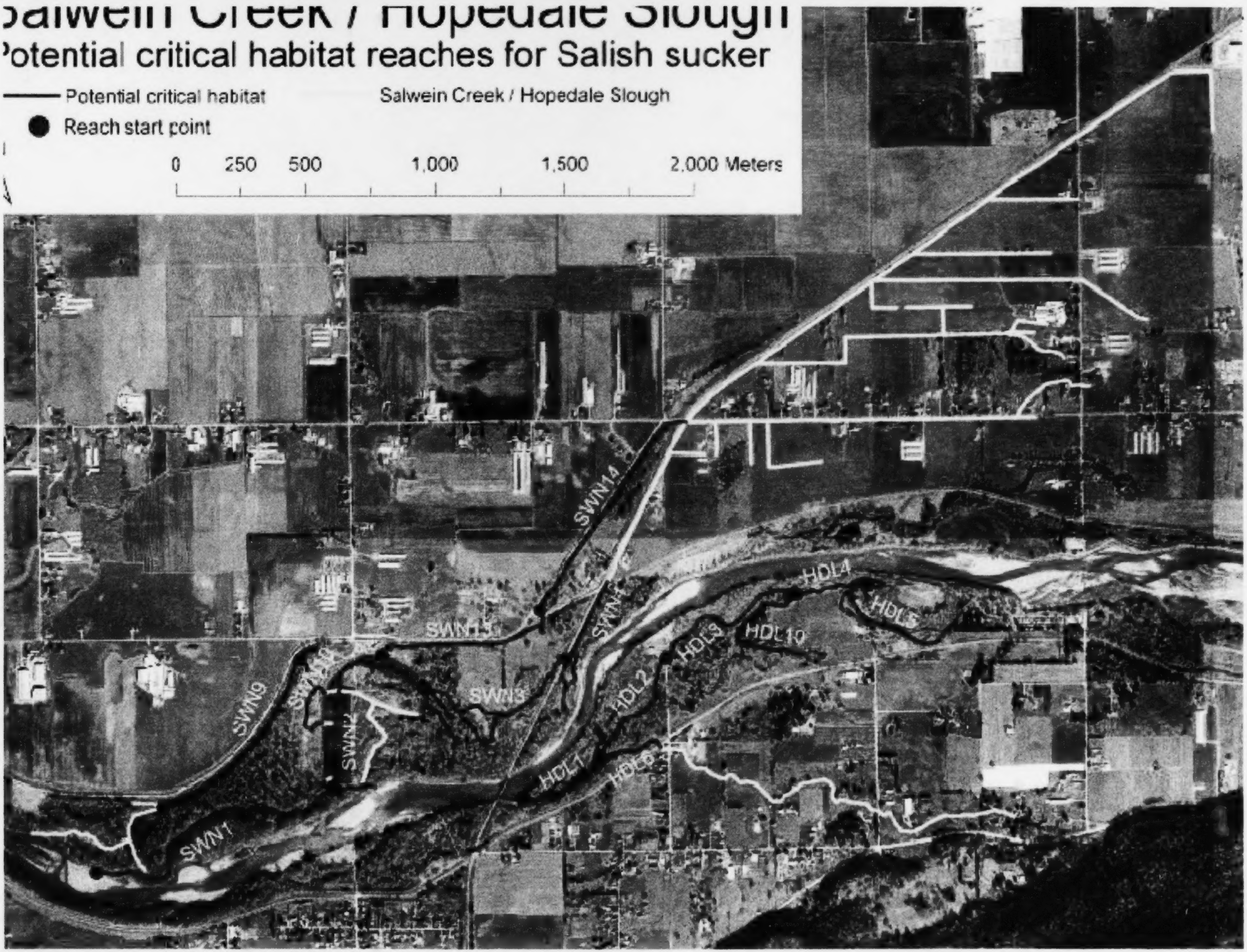
Salmon River

Potential critical habitat for Salish sucke

Potential critical habitat
Reach start point
Salmon River
0
1,000
2,000
4,000
6,000 Meters
N
SLN6


Salmon River
Potential riparian critical habitat
Width (m) 30 25 20 15
Permanent structures
Salmon River
N
0 1,000 2,000 4,000 Meter
Fraser River
Fort Langley
Aldergrove

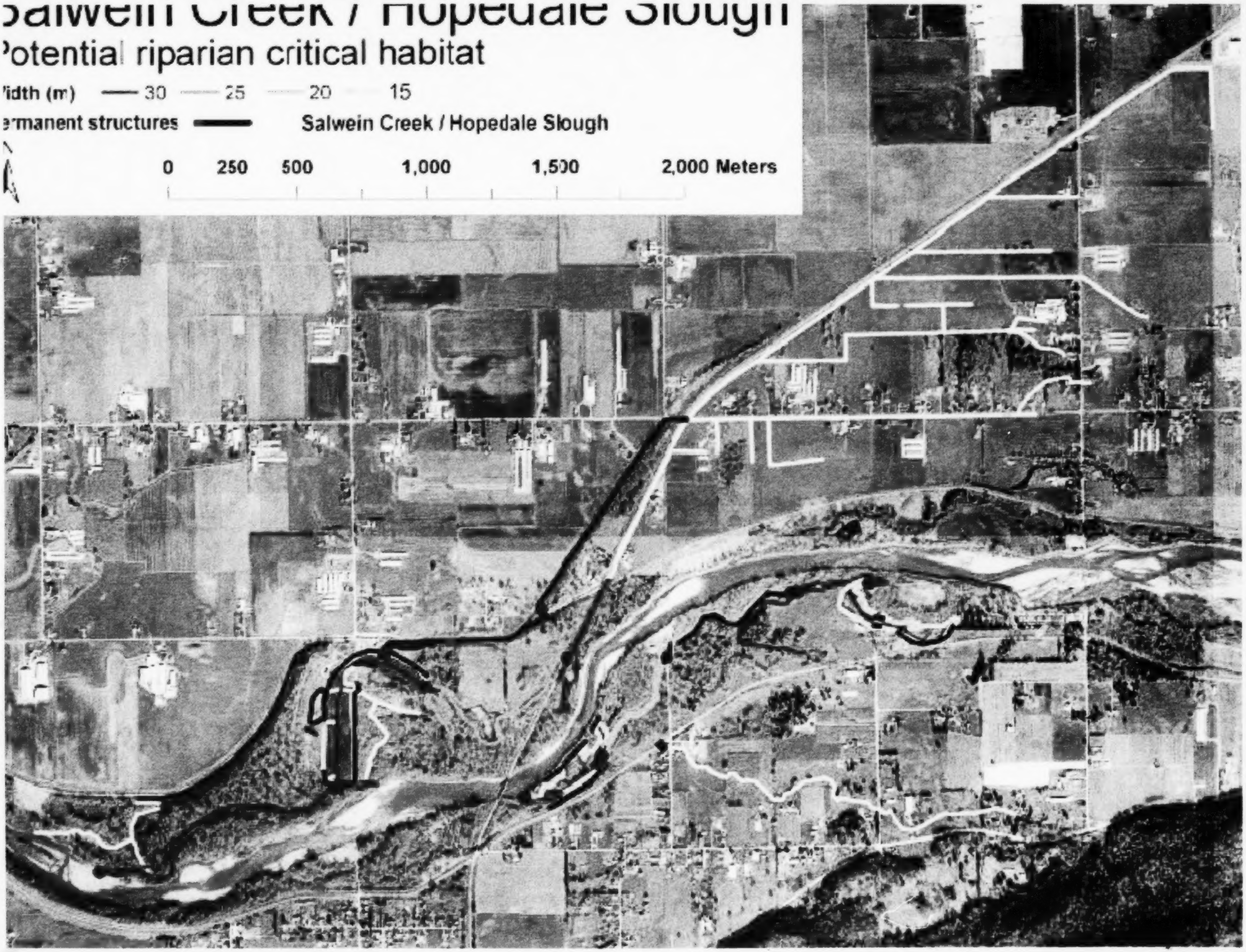

Salmon River
Existing riparian vegetation, 2004
Width Category
5
15
30
5
Salmon River
N
0
1,000
2,000
4,000 Mete
Fraser
River
Fort
Langley



alwein Creek / Hopedale Slough

otential critical habitat reaches for Salish sucker

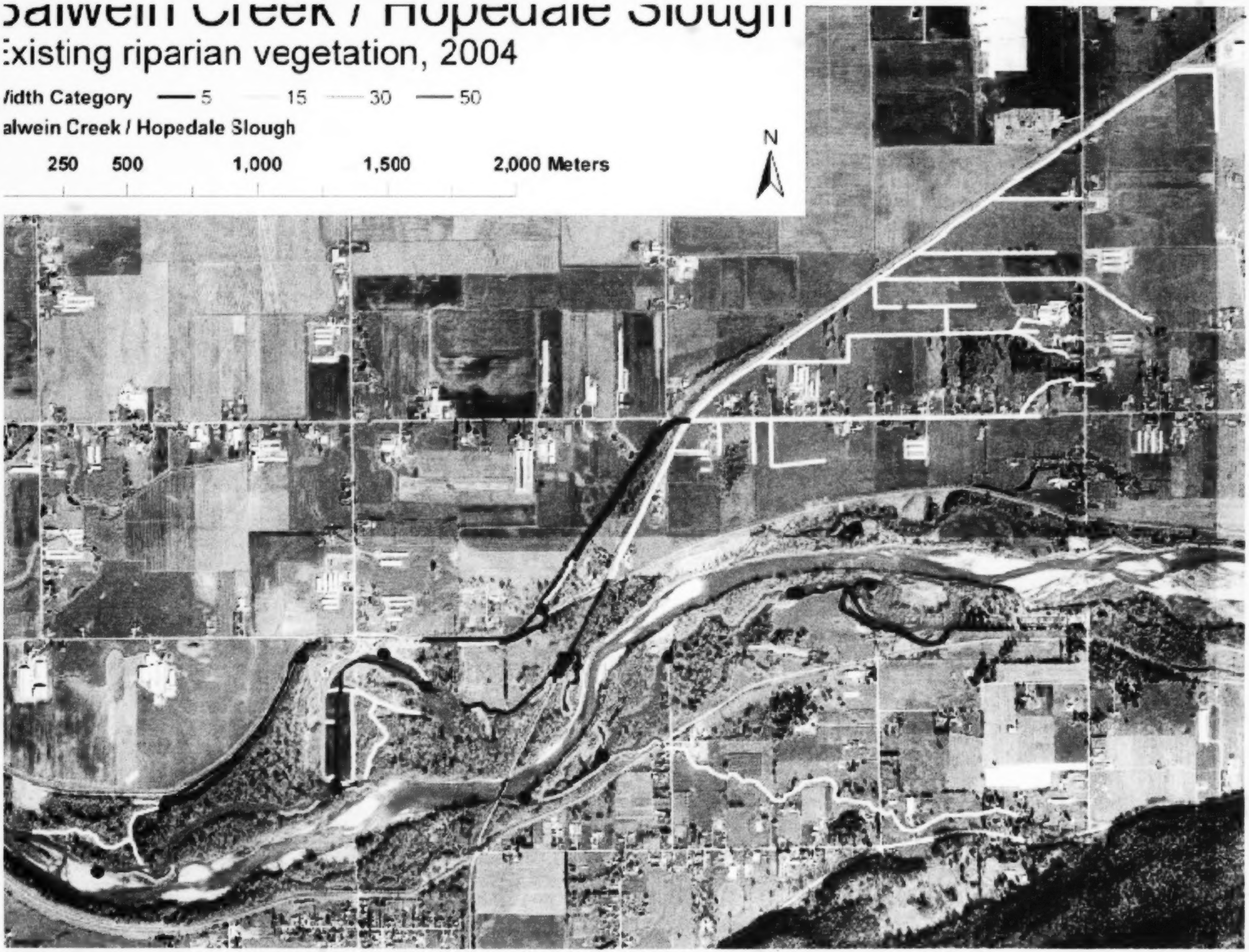
Potential critical habitat
Reach start point
Salwein Creek / Hopedale Slough
0
250
500
1,000
1,500
2,000 Meters
SWN14
SWN4
SWN13
SWN10
SWN9
SWN3
SWN2
SWN1
HDL4
HDL5
HDL10
HDL3
HDL2
HDL1
HDL6



Salwein Creek / Hopedale Slough

Potential riparian critical habitat

Width (m)
30
25
20
15
ermanent structures
Salwein Creek / Hopedale Slough
N
0
250
500
1,000
1,500
2,000 Meters



alwein Creek / Hopedale Slough

xisting riparian vegetation, 2004

idth Category
5
15
30
50
alwein Creek / Hopedale Slough
250
500
1,000
1,500
2,000 Meters
N